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BRITISH LOCOMOTIVES IN 1925

DESIGNS AND WORK,

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Figs. 1 to 5, pp. 76 and 73.

I. — Designs

As the year which witnessed the celebration of the Railway Centenary (in July), it is only fitting that several outstanding new locomotive designs should also have to be credited to 1925. Two of these, moreover, inaugurate features novel to British locomotive practice, these being further of interest in that they have both been introduced on the London & North Eastern Railway, the system principally concerned in the Centenary proceedings, as it incorporates the old Stockton & Darlington Railway, publicly opened in September, 1825.

One of these, Mr. H. N. Gresley's 2-8-8-2 *Garratt* engine (fig. 1, *a*), ranks as the first articulated locomotive to be introduced upon a standard railway in Great Britain. It is true that it is not the first *Garratt* engine to be placed in service within the British Isles, in that there is already a small engine of this type at work on a private industrial railway in South Wales, while there are also two or three old narrow-gauge articulated engines of the *Fairlie* double-boiler type. The London & North Eastern *Garratt* engine is, however, the first to be adopted on a standard railway, and the design is further remarkable in that each section has three cylinders, so that it has the additional distinction of being the first six-cylinder *Garratt* locomotive in the world. It is, moreover, considerably the largest and most powerful locomotive in the British Isles.

Mr. Gresley has also placed in service

a three-cylinder 2-8-2 locomotive (fig. 2, *b*) for heavy freight traffic, this being a considerable development upon his three-cylinder 2-8-0 locomotive. It is the first 2-8-2 main line tender locomotive to be introduced into British practice, and is further notable in that it is fitted with a « booster » to the trailing wheels.

So far as other railways are concerned, the new designs of the year represent ordinary developments rather than novelties, though, as will be seen, in two cases (fig. 4, *d*, and fig. 5, *e*) the designs are more or less novel to the railway concerned, and a somewhat interesting story attaches to them.

In the case of the London Midland & Scottish Railway, although there is nothing calling for special remark this year, two notable designs are on the verge of completion, and engines according to each may be in service by the time this article is published. One of these is a 2-6-0 class put in hand by Mr. George Hughes, who, as mentioned at the close of last year's article, has just retired from the position of chief mechanical engineer of the London Midland & Scottish Railway, but the engines are being completed under the direction of Sir Henry Fowler, K. B. E., who was previously deputy chief mechanical engineer but who has now assumed the full responsibilities of the department. This will make a very useful mixed-traffic type, available for use on all parts of the system.

The other is a *Garratt* design (*i*), smaller than that of the London & North Eastern Railway already in service, though still of considerable size and power. This will be of the 2-6-6-2 type, with two cylinders only to each section, and is intended for working heavy goods and mineral trains between Toton, in the Derbyshire coal district, and Brent Sidings, Hendon, near London, a route upon which long and heavy coal trains are operated in considerable numbers. The engines are being introduced to enable full loads to be operated throughout without requiring an assistant engine, as is frequently necessary under present conditions. There are to be three of these engines, and, as in the case of the London & North Eastern Railway *Garratt*, they are being constructed by Messrs. Beyer, Peacock & Co., Ltd., the owners of the *Garratt* patents.

Otherwise, practice on the London Midland & Scottish Railway has related mainly to the multiplication of designs already in service, particularly the addition of considerable numbers of three-cylinder 4-4-0 compound engines of Midland pattern but with 6 ft. 9 in. coupled wheels, as described in last year's article, and a large number of superheater 0-6-0 locomotives, also of Midland pattern. Both classes are being extensively used on all sections, in Scotland as well as in England.

Under Sir Henry Fowler's auspices, several new 2-8-0 superheater engines (*g*) of a class introduced some years ago for heavy gradient freight traffic on the Somerset & Dorset Joint Railway (jointly owned by the London Midland & Scottish and Southern Companies), have been placed in service. They have been built by Messrs. Robert Stephenson & Co., Ltd., of Darlington, but correspond generally with the original series, except for minor modifications in accordance with modern practice. One of these engines was shown at the Railway Centenary Exhibition, in association with a model of the old Stockton & Darlington engine *Locomotion*, thus emphasising the interesting fact that this firm of builders had been

responsible for constructing each of the engines, though 100 years apart.

On the London & North Eastern Railway, apart from the *Garratt* and *Mikado* locomotives above mentioned, additions have been mainly to classes already in service, and the principal item of interest otherwise is that, for service on various sections, a new class of 0-6-2 superheater tank engine (*h*) has been introduced, generally similar to corresponding locomotives on the Great Eastern section, but incorporating features of what is now recognised London & North Eastern Railway practice. Dimensions of these engines are given in the table.

On the Great Western Railway further engines of the *Castle* class have been added, and several of the older four-cylinder locomotives of the *Star* class have been rebuilt, so that they have become, to all intents and purposes, modern engines of the present *Castle* class. In addition, one or two of the older two-cylinder 4-6-0 class have been converted into mixed-traffic or steep gradient express locomotives (*f*) by changing their 6 ft. 8 1/2 in. coupled wheels for wheels 6 feet in diameter, with other incidental alterations. The boiler is of the type originally fitted, but the cab is modelled on the lines of those of the *Castle* class engines. Otherwise, locomotive practice on the Great Western Railway has consisted mainly in the addition of new engines of various standard designs, and a considerable amount of ordinary rebuilding and reboilering of locomotives from the various smaller railways which have been incorporated in the Great Western system as a result of grouping.

On the Southern Railway the principal feature of interest is the introduction of what is known as the *King Arthur* class of 4-6-0 locomotives (fig. 3, *c*). These have a degree of similarity to Mr. Urie's 4-6-0 locomotives as introduced on the late London & South Western Railway. In preparing the new design, however, Mr. R. E. L. Maunsell had to take into account the fact that the engines would have to be able to work over sections of the late South Eastern & Chatham Railway, and particularly the working of the heavy Continental boat trains between Victoria station, London, and Dover. The design has thus been prepared in view of certain weight and dimensional limitations which did not apply to Mr. Urie's engines, though when the *King Arthur* class is referred to generally it includes the *Urie* express 4-6-0 locomotives. The class engine, No. 453E, *King Arthur*, although actually a new engine, ranks as a rebuild, replacing the Drummond 4-6-0 which previously bore the same number. The same action has been taken in regard to a number of other engines, while a further series of entirely new locomotives has been constructed by the North British Locomotive Co., Ltd., to the same designs. The engine shown in figure 3 is one of this series.

Previously, no London & South Western modern locomotives carried names, while the practice was dying out on the London, Brighton & South Coast section of the Southern Railway. With the appearance of the *King Arthur* class, however, the practice of naming engines has been adopted for all new Southern Railway express locomotives, names for the *King Arthur* series, with which the Urie 4-6-0 locomotives mentioned are associated, being taken from the King Arthur legends. Partly for this reason, and partly because of the notable work which the engines have been doing, the *King Arthur* class has become very popular with the large public which takes a keen interest in locomotive developments and running performances. It may be men-

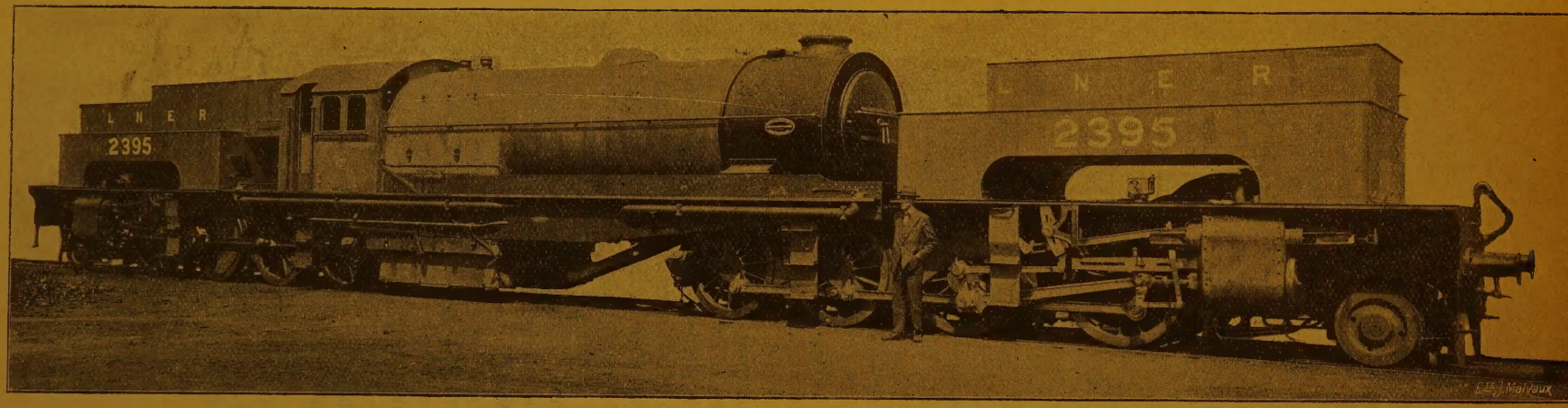

Fig. 1. — Three-cylinder 2-8-8-2 *Garratt* locomotive. London & North Eastern Railway.
Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer.

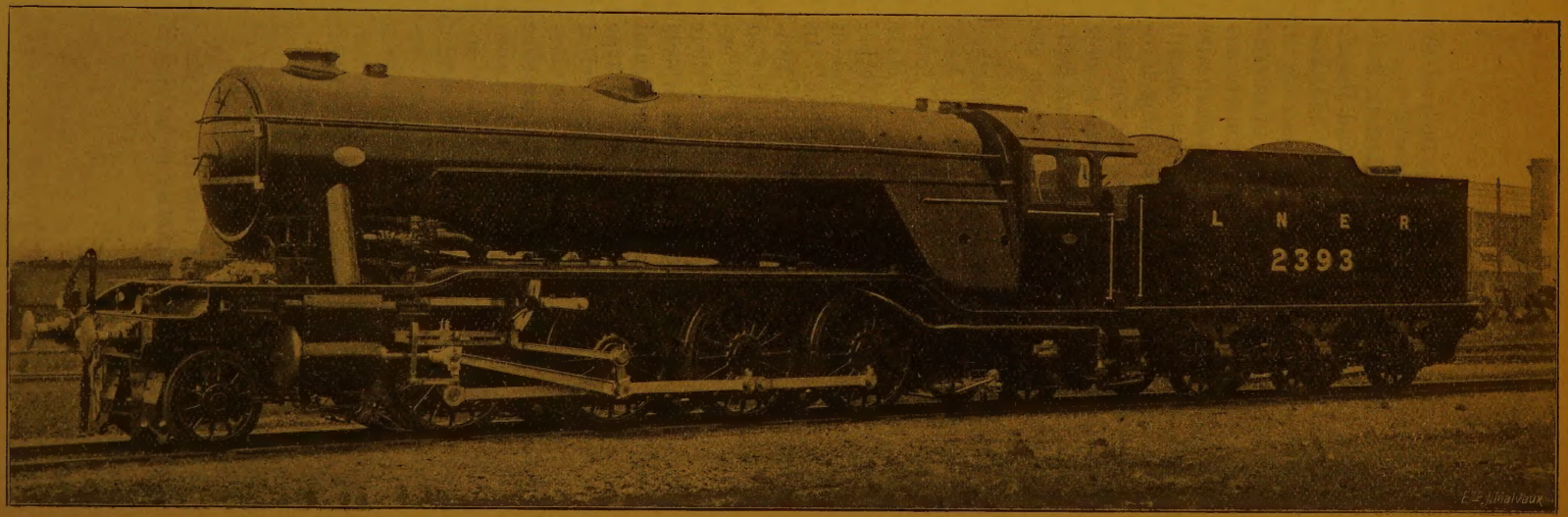

Fig. 2. — Three-cylinder 2-8-2 locomotive, London & North Eastern Railway.
Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer.

tioned that several other classes of main line locomotives already in service are being named, usually in groups having names of a particular character.

Mention may also be made of the fact that Mr. Maunsell has built a number of new 2-6-4 express tank engines, corresponding to the pioneer engine he introduced on the South Eastern & Chatham Railway some years ago. These are for service on certain routes of the Brighton section where Mr. Billinton's biggest classes of express tank engines are not allowed to run, as also on the same turns as the 4-6-4 tank locomotives. The new 2-6-4 tank engines (*k*), in conformity with the new practice of naming, are known as the *River* class. A further series of these engines is under construction, and one (completed January, 1926) is fitted with three cylinders. Further 4-4-0 engines are also under construction for the Southern Railway, but they will belong to the record of 1926.

So far as other railways are concerned, principal interest attaches to some 2-6-4 tank engines placed in service on the Metropolitan Railway (fig. 4, *d*), described later, and to certain developments on Irish lines. Following the example of the railways in Great Britain, all except one big system and a very few small and light railways in the Irish Free State have been amalgamated to form what are now known as the Great Southern Railways, the only exception being, in fact, the Great Northern Railway of Ireland, which, owing to the fact that it has important interests in both the Irish Free State and in Northern Ireland could not well be included in the grouping scheme. Speaking generally, however, no special developments in the way of new designs can yet be associated with grouping, but two pre-grouping designs placed in service during 1925 call for mention. One of these is a 2-6-0 mixed-traffic class intended for the Midland Great Western Railway of Ireland (fig. 5, *e*), while the other is a further series of 4-4-2 tank engines ordered by the Dublin & South Eastern Railway. In Northern Ireland, the Great Northern has added a few new engines of standard classes, and has rebuilt a number of older engines, while on the Northern Counties system ordinary rebuilding and replacement work has been carried on, but the only item of special interest is a class of 4-4-2 tank engines placed in service on the Belfast & County Down line.

It will now be in order to describe engines referred to above in greater detail.

Figure 1, *a* shows the London & North Eastern *Garratt* locomotive mentioned. It is being employed for banking duty on a very steeply graded branch in a mineral district, on which it replaces two or even three banking engines sometimes required when heavy mineral trains, weighing as much as 1 000 tons, have to be operated over a 7-mile incline, of which 2 miles are at 1 in 40. This requirement explains why so exceptionally powerful a locomotive is necessary, though, notwithstanding its unusual type and large dimensions, the weight distribution is such that the engine could be, if need arose, run over practically any main route. Having three cylinders for each of the engine units, the engine is, of course, able to exert very great power, while the *Garratt* design permits of a boiler of exceptional dimensions being employed. In this case the barrel has a maximum diameter of 7 feet, while the total heating surface, including superheater, is no less than 3 640 square feet. The grate area is correspondingly large, being 56.4 square feet, while the total weight — 178 tons — far exceeds that of any

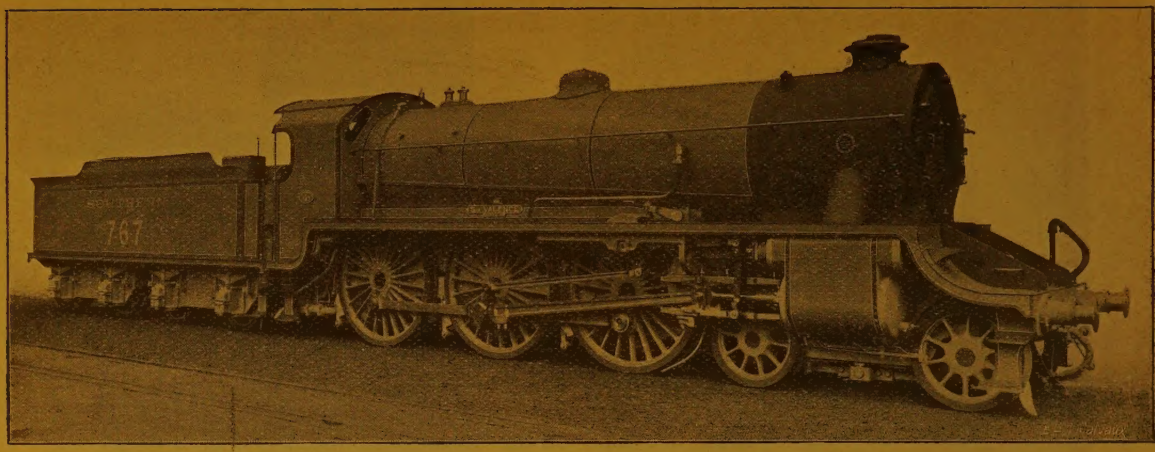

Fig. 3. — 4-6-0 Express locomotive, Southern Railway.
Mr. R. E. L. Maunsell, C. B. E., Chief Mechanical Engineer.

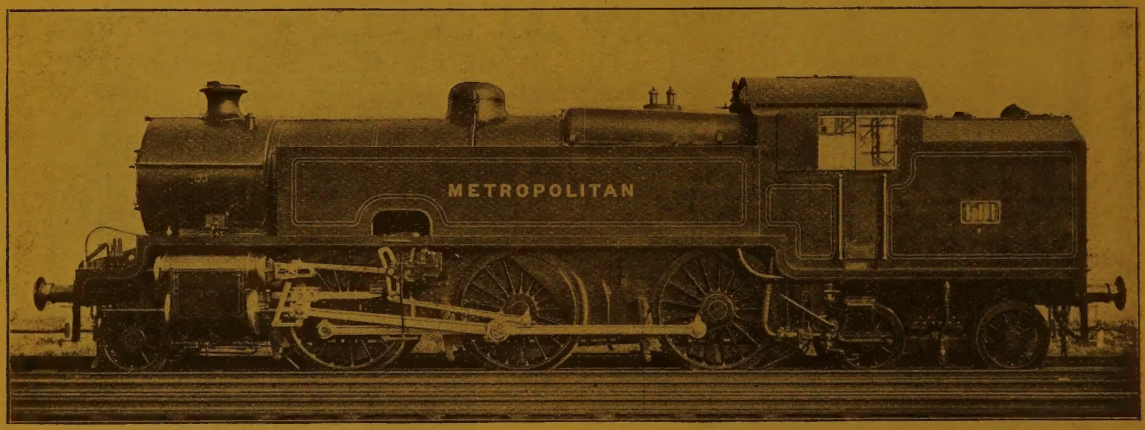

Fig. 4. — 2-6-4 Tank engine, Metropolitan Railway.
Mr. G. Hally, Mechanical Engineer.

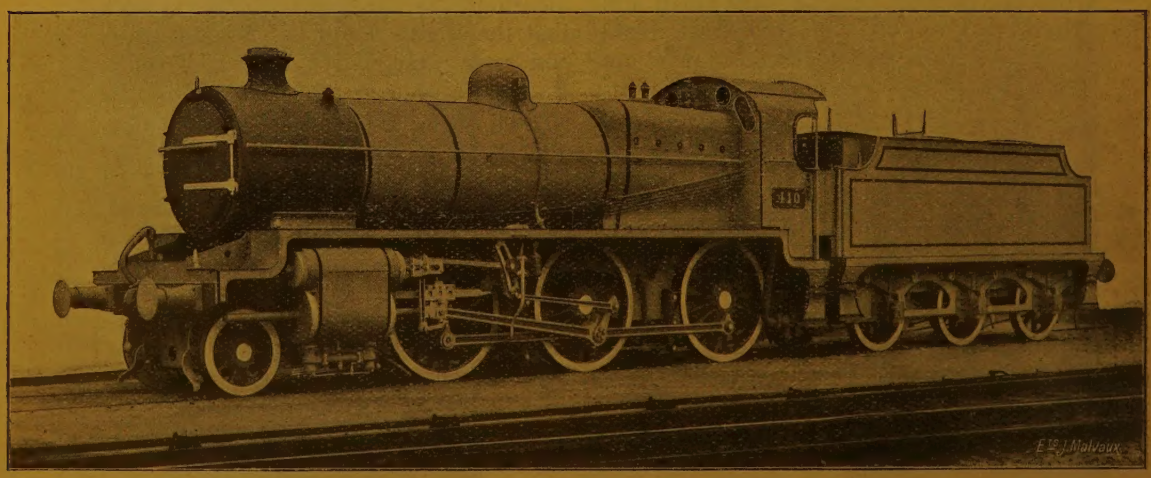

Fig. 5. — 2-6-0 Locomotive, Great Southern Railways (Ireland).
Mr. W. H. Morton, Deputy Chief Mechanical Engineer.

engine hitherto placed in service on a British railway.

Figure 2, *b* illustrates Mr. Gresley's 2-8-2 locomotive. This is intended mainly for working very heavy freight trains on the main line, and particularly between Peterborough and London. As already indicated, it is based upon the three-cylinder 2-8-0 locomotives already in service, but has a larger boiler, and, with the addition of a booster, is intended to be able to work 100-wagon trains representing weights up to 1 600 tons behind the tender. The coupled wheels are, moreover, 6 inches larger than those of the 2-8-0's, in order to obtain greater speed capacity on the clear runs. The boiler is practically that fitted to Mr. Gresley's *Pacific* locomotives. The booster has two cylinders, 10 inch diameter and 12 inch stroke, and drives the trailing wheels, which have a diameter of 3 ft. 8 in. Further engines of this class are being added in view of the successful results given by No. 2393. Both the *Garratt* and the *Mikado* figured in the procession of locomotives which constituted a leading feature of the Railway Centenary celebrations at Darlington in July.

Figure 3, *c* shows one of the *King Arthur* class locomotives built by the North British Locomotive Company to the order of the Southern Railway. These engines, together with others which rank with them, now take a considerable share in the main line working of the London & South Western section, but, in addition, several of them are now engaged in working the heavy Continental expresses between Victoria station, London, and Dover. This route was handicapped by the fact that bridges and other engineering restrictions prevented 4-6-0 locomotives being employed, and for part of its length was not allowed to be used even by the largest and most powerful 4-4-0 engines available. The change has, of course, been practicable only in consequence of the rebuilding and strengthening of some of the bridges on the route to permit of the passage of these big engines. The design, however, has involved taking into account certain other restrictions which prevented big locomotives of existing classes being used on the run.

With a view to finding employment for workers who had been brought together for work at Woolwich Arsenal during the war, some of the shops there were adapted for locomotive construction. One design only was taken in hand, the 2-6-0 mixed-traffic class which Mr. R. E. L. Maunsell had introduced on the South Eastern & Chatham Railway. A number of engines were constructed, and most of these have been taken over by the Southern Railway, which now has a considerable number of engines of this class in service, including, of course, those which were built in its own workshops. When locomotive construction was stopped at Woolwich Arsenal, however, besides completed engines a number of sets of parts were available, and the engines shown in figures 4 and 5 both represent utilisation thereof.

In the case of the Metropolitan Railway a design was prepared utilising some of these parts, and six engines were built by Messrs. Armstrong, Whitworth & Co., Ltd., under the oversight of Mr. G. Hally, mechanical engineer, Metropolitan Railway. Many dimensions necessarily correspond with those of Mr. Maunsell's 2-6-0 tender engines. In other respects, however, the design is new or in accordance with Metropolitan Railway standards for steam locomotives. The engines are being used mainly for

LEADING DIMENSIONS OF LOCOMOTIVES ILLUSTRATED AND DESCRIBED.

T = Tank engine. — G = Garratt articulated design. — B = Fitted with « Booster ». — R = Rebuilt.

Reference.	Figure.	RAILWAY.	Type.	Cylinders. Diameter and stroke (inches).	Diameter of coupled Wheels.	Heating surface (square feet). Tubes.	Heating surface (square feet). Fire box.	Heating surface (square feet). Superheater.	Grate area (square feet).	Steam pressure (lb. per square inch).	Weight (engine only) in working order (tons).
(*a*)	1	L. N. E.	2-8-2 G	18 1/2 × 26 (6)	4' 8"	2757	237	646	56.4	180	178
(*b*)	2	L. N. E.	2-8-2 B	20 × 26 (3)	5' 2"	2715	215	525	41.3	180	100
(*c*)	3	Southern	4-6-0	20 1/2 × 28	6' 7"	1716	162	337	30	200	81
(*d*)	4	Metropolitan	2-6-4 T	19 × 28	5' 6"	1390	135	285	25	200	87.5
(*e*)	5	Great Southern (Ireland)	2-6-0	19 × 28	5' 6"	1390	135	285	25	200	61
(*f*)	...	G. W.	4-6-0 R	18 1/2 × 30	6' 0"	1681	155	263	27	225	72.5
(*g*)	...	S. & D. Joint	2-8-0	21 × 28	4' 7 1/2"	1323	148	373	23.4	190	68.6
(*h*)	...	L. N. E.	0-6-2 T	18 × 24	4' 10"	858	110	134	17.7	180	63.7
(*i*)	...	L. M. S.	2-6-6-2 G	18 1/2 × 26 (4)	5' 3"	1994	186	480	44	180	141
(*k*)	...	Southern	2-6-4 T	19 × 28	6' 0"	1391	135	285	25	200	82.6

working freight trains over the steep gradients of the joint London & North Eastern and Metropolitan line between Finchley Road and Aylesbury, Chesham, Watford and Verney Junction.

In the case of the Great Southern Railways locomotives, similar sets of parts have been utilised, somewhat on the lines of the original design but adapted for the Irish gauge of 5 ft. 3 in. and incorporating fittings and details in accordance with Midland Great Western Railway standards. As this work was put in hand before the Midland Great Western Railway became part of the Great Southern system, Mr. W. H. Morton (who now has the title of deputy chief mechanical engineer, Great Southern Railways) has been responsible for the work of construction, though the engines now go into the general Great Southern Railways list.

A few notes may be added with regard to engines of which particulars are given in the table but not illustrated. The new Somerset & Dorset 2-8-0 locomotive (*g*) has a boiler somewhat larger than that fitted to the class as originally built, while it is adapted for left-hand instead of right-hand drive. Ross « pop » safety valves are used instead of the Ramsbottom type, while mechanical lubrication has been fitted to the coupled axle boxes. The latter has been done also in the case of the older engines. The tender is of standard type, without the cab fitted to the other engines of the class.

The Great Western rebuilt 4-6-0 locomotive (*f*) above mentioned as having been converted from express to mixed-traffic, with 6 feet instead of 6 ft. 8 1/2 in. coupled wheels, although it still carries a boiler of the type originally fitted, has a cab modelled on the lines of those of the *Castle* class engines.

Modifications are also made in the brake and reversing gear.

The Belfast & County Down 4-4-2 tank engines mentioned were constructed by Messrs. Beyer, Peacock & Co., Ltd. The same applies to some new Great Southern of Ireland 4-4-2 tank engines, in regard to which it is necessary to point out that they were supplied to the order of the Dublin & South Eastern Railway but are now, of course, included in the general Great Southern Railways stock.

II. — Work.

While the summer train services of 1925 included but few actual novelties, there was a certain amount of speeding-up on most lines and a number of interesting changes were made, though, speaking generally, there are none which call for special remark here, except with reference to the working of Pullman car trains between London (King's Cross) and Edinburgh. This train — at first intended to run only between London and Harrogate and Ripon, but afterwards altered to serve Leeds and Bradford and extended to Newcastle — was in the summer given a further extension through to Edinburgh, travelling *via* Leeds. Under those circumstances, the train was generally worked by a Great Central type four-cylinder 4-6-0 locomotive between King's Cross and Leeds (non-stop), in view of the heavy gradients and many service slacks between Doncaster and Leeds. From 21 September, however, it was replaced by two trains, one for Leeds and Bradford (and from Harrogate in the opposite direction), and the other through between King's Cross and Edinburgh (Waverley) *via* Harrogate and Ripon, but adopting a different route between Doncaster and Harrogate from that taken by the Leeds train. As thus altered, the Edinburgh train became booked between London and Edinburgh in 8 1/4 hours, the same time as the principal day Anglo-Scottish expresses by the East Coast route, and had the further distinction of making the run to Harrogate (198.4 miles) non-stop in 220 minutes one way and 223 minutes the other. The Pullman express between London and Sheffield, a run with which was described last year, was withdrawn.

On the basis of the 1925 summer train services the London Midland & Scottish Railway had 68 non-stop runs ranging between 100 and 219.5 miles, the highest average speed represented being 59.2 for a run of 107.5 miles between Willesden Junction and Birmingham (New Street); the London & North Eastern Railway had 50 runs ranging between 100 and 188.2 miles (without counting the London-Harrogate run of 198.4 miles introduced later), average speeds ranging up to 57 miles per hour; and the Great Western Railway had 26 runs of from 100 to 226.9 miles, the highest average being 61.1 miles per hour by two trains serving Bath (106.9 miles from Paddington) by a slip service, or 59.2 miles per hour for the start to stop run of 118.3 miles in 120 minutes between Paddington and Bristol, *via* Bath. In the case of the Southern Railway, four trains were booked to make the non-stop run between Waterloo and one or other of the Bournemouth stations, slightly over the hundred miles.

In regard to fastest runs, the Great Western Railway has maintained its schedule of 75 minutes for the 77.3 miles between Swindon and Paddington, and the London & North Eastern Railway its runs between Darlington and York and between Leicester and Arkwright Street, Nottingham, at 61.5 miles per hour, though the London Midland & Scottish,

London & North Eastern and Great Western Railways all have several other trains booked at only slightly below the mile-a-minute rate.

The great event of the year was, however, the trial which took place in the Spring, when a London & North Eastern 4-6-2 engine worked non-stop trains between Paddington and Plymouth, Great Western Railway, turn for turn with a Great Western *Castle* class engine, and one of the latter engines worked selected trains on the London & North Eastern Railway against one of that company's 4-6-2 locomotives. The result was inconclusive in some respects, in that it has been argued that the reports, as published on the authority of the Great Western Railway, do not sufficiently take into account one or two complicating factors. The main point at issue appears to be that, whereas the London & North Eastern Railway locomotive working on the Great Western Railway maintained strict schedule times, the Great Western Railway locomotive working as its « opposite » on several occasions ran markedly in advance of booked times. The London & North Eastern Railway locomotive, owing to its long wheelbase and the fact that its weight was such that it came only just within the engineering restrictions of the Great Western Railway, had to be held in somewhat on the down grades, so that schedule time was mainly kept by notable work on the less favourable sections. Further, the London & North Eastern Railway engine intended to work against the Great Western locomotive running on the London & North Eastern Railway line failed on the first day, and the substitute engine which took up its duty does not seem to have acquitted itself quite up to the standard generally realised by the class as a whole. These points are mentioned, however, only to indicate the extent to which trials of this kind tend to be inconclusive. It appears to be beyond question, however, that on the ground of coal consumption the Great Western *Castle* class locomotive not only showed a considerable superiority as compared with the London & North Eastern Railway engine working against it on the Great Western line — an understandable result seeing that the « stranger » locomotive was using coal of a different quality from that to which its men were accustomed — but the Great Western locomotive working on the London & North Eastern Railway also gave better coal consumption results than the London & North Eastern Railway engines with which it compared, notwithstanding that the Great Western locomotive was using coal of the quality to which the London & North Eastern Railway men were accustomed.

Several further points of interest arose. Thus, on the Great Western line, the Great Western locomotive concerned gave early arrivals of 5, 3 and 15 minutes on the down journey, and 14 1/2, 4 and 7 minutes on the up journey, whereas only in one or two instances did the London & North Eastern Railway locomotive improve upon schedule, and then only to the extent of a minute or two. On the London & North Eastern Railway the notable feature of the work by the Great Western locomotive was the very fast time in which Finsbury Park was passed, bearing in mind the steep gradients through greasy tunnels which have to be faced immediately on leaving King's Cross station. The Great Western locomotive also improved appreciably upon schedule time. It must be borne in mind, too, that all the runs concerned involved practically the maximum loads to which the trains concerned are liable, vehicles being added in one or two instances to

achieve this result, so that the comparisons involved were made as fair as possible, the only variable elements being weather and one or two signal or other delays which occurred in the course of working.

From the statement as to the results of the trial, the outstanding point which seems to arise is that considerable value attached to the fact that the Great Western locomotives were working at a pressure of 225 lb. per square inch, as compared with 180 lb. in the case of the London & North Eastern Railway locomotives. The high pressure enables the Great Western Railway to work its heavy traffic, including the very difficult London-Plymouth non-stop run when a full load is taken, with the aid of an engine of relatively moderate dimensions. The London & North Eastern Railway locomotive represents the alternative practice of larger boiler capacity provided by a boiler which requires an additional pair of wheels to carry it and to allow for the wide type of firebox used.

As published in the *Great Western Railway Magazine*, the following comments upon the results were made :

The analysis which has been prepared of the trips shows that on the London & North Eastern line the Great Western *Castle* did consistently better than the London & North Eastern *Pacific* running against it on alternate days. On the Great Western line the London & North Eastern *Pacific* did well in regard to timekeeping. The *Castle* engine put up splendid performances, particularly on the heavy trains of the down *Limited*, as it arrived at Plymouth well before time each day.

Taking into account the coal consumption, the results show that the Great Western engine is more economical both with the Welsh coal on the Great Western line and with the Yorkshire coal on the London & North Eastern line. The average consumption of the Great Western engine for the trips on the Great Western line was 6 lb. of coal per mile less, and on the London & North Eastern line 3.7 lb. per mile less, than that consumed by the corresponding London & North Eastern engine.

The *Great Western Railway Magazine* also suggested that :

The results prove that the Great Western four-cylinder engine of the 4-6-0 type with a weight of 119 tons 17 cwt. can handle the same trains as the London & North Eastern three-cylinder engine of the 4-6-2 type with a weight of 148 tons 15 cwt. with equal, and in some sections greater, facility, and with a lower consumption of fuel. The slightly less weight on the coupled wheels of the *Castle* proved no drawback, as it was noticeable that the starts from King's Cross and the subsequent timing to Finsbury Park and Potters Bar were, on each trip superior to the performance of the *Pacific* engine working against it.

To compare with this the London & North Eastern Railway issued a statement, from which the following notes may be given :

The tests between the London and North Eastern *Pacific* engine and the Great Western *Castle* engine were carried out with loads of from 345 tons to 500 tons, but the London and North Eastern *Pacific* was designed for working loads up to 600 tons, which it has done successfully.

The coal consumption of the *Castle* engine was lower than the *Pacific*. This amounted to about 7 lb. of coal per thousand ton-miles, and the lower coal consumption was obtained by the increased boiler pressure carried by the Great Western engine. The saving, however, in cost of coal is discounted by

the increased cost of maintaining a boiler having 45 lb. per square inch higher pressure.

The *Pacific* engine on the Great Western was not able to run on the falling gradients at as high a speed as on the London & North Eastern main line. It was found that with the extra weight, and with the larger boiler necessarily placed higher from the rails, the weak spots in the Great Western Railway permanent way set up considerable oscillation. Consequently, in order to maintain punctuality, a higher speed than scheduled was necessary and attained on the rising gradients, and naturally this involved greater coal consumption. As an instance, from Westbury to Savernake the London and North Eastern Railway *Pacific*, with a load of 345 tons, passed over the top of this gradient at 64 miles per hour, having run the whole 25 1/2 miles in 26 minutes, a feat never yet recorded by the Great Western engine with a similar load.

The Great Western road to Plymouth is very hilly, and has many severe curves with speed restrictions, whereas the East Coast main line is practically free from both. An intimate knowledge of the road was not attainable in the short period of the tests and placed the *Pacific* enginemen at a considerable disadvantage. The actual figures relating to coal consumption show that this was so, as the *Pacific* performance improved as the trials proceeded.

Bearing in mind that the Great Western Railway, some 15 years ago, introduced a *Pacific* locomotive, the famous *Great Bear*, though its performances were hindered by the fact that its long wheelbase and great weight rendered it necessary to prohibit it from working except between London and Bristol, so that it could not be used on special runs such as the one between London and Plymouth, the question naturally arose as to why, if a Great Western 4-6-2 could not be used, a London & North Eastern Railway 4-6-2 could. In answer to this it was pointed out that the London & North Eastern Railway locomotive came just within the permissible limits, though it could not be allowed to make more than a few runs, whereas these limits were exceeded by the Great Western Company's own engine, which, by the way, has now been converted to a 4-6-0, as mentioned in last year's article.

The writer travelled to Plymouth on the first of the test runs, behind the London & North Eastern Railway locomotive working on the Great Western. London & North Eastern Railway 4-6-2 No. 4474 had a load which was almost exactly 500 tons. The start from Paddington was slightly slower than usual, owing, to slipping, but the engine soon got the train in hand, though at Reading it was still slightly behind schedule, in that 37.7 minutes had been taken for the 36 miles. Thence to Savernake, an almost continuous climb, the 34.1 miles were covered in 36.7 minutes, and at Westbury, where two vehicles were slipped at the usual reduced speed, 95.6 miles had been covered in 98.5 minutes. The further necessity for reduced speed at Frome rendered the running for the next few minutes somewhat slow, as is usually the case. At Taunton the 141.9 miles had been covered in 147.2 minutes. From Taunton to Whiteball Summit Box the 11.9 miles were run in 12.7 minutes, and the 19.9 miles down to Exeter (passed slowly) in 18 minutes 25 seconds, so that at Exeter the 173.7 miles had been run in 178 minutes 25 seconds. By this time the load had been reduced (by the Westbury, Taunton and Exeter slips) to eight 70-foot cars, the usual maximum

unpiloted on the Newton Abbot to Plymouth section, and allowing for the speed reductions entailed between Exeter and Newton Abbot, the latter station, 193.9 miles, was passed in 202.2 minutes. Up the very steep gradients of the Newton Abbot-Plymouth section, in places as severe as 1 in 36, 1 in 43 and 1 in 51, the engine seemed to deal with its load quite easily, and a careful run down, with a slight permanent way check near Laira Junction, brought the train into North Road station practically on the stroke of 2.37 p. m., so that the 225.7 miles had been covered exactly in the schedule time of 247 minutes, without any apparent undue effort on the part of the engine.

On the same day a colleague travelled with the train worked by a Great Western locomotive on the London & North Eastern Railway, No. 4079, *Pendennis Castle*, being the engine concerned. The load was 456 tons. The severe gradients through the tunnels out of King's Cross were mounted with comparative ease, and Finsbury Park was passed in the notable time, for such a load, of 5.8 minutes. The difficult stretch of nine miles to Potter's Bar took barely 14 minutes, so that the initial test length of 12.7 miles from King's Cross to Potter's Bar had been run in 19.5 minutes, a particularly good time with so heavy a load. Thereafter a comparatively steady speed was maintained, Stevenage (28.5 miles) being passed in 35 minutes and Huntingdon (58.5 miles) in 61 minutes, maximum at Three Counties, 83.3 miles per hour. The fall of 1 in 200 from Abbots Ripton to the level at Holme gave more good running, and Peterborough (76.4 miles) was reached 3.2 minutes ahead of booked time. Leaving 2.3 minutes late, owing to station delays, the mainly adverse gradient from Peterborough to Stoke Box was mounted steadily until the run was spoiled by a severe permanent way check and speed restriction from Corby to Stoke, the previous 15.8 miles having been covered in 18.3 minutes. The final 1 in 200 and 1 in 178 from Corby to the top of the bank were covered at steady speed, but, as a result of the inevitable delays due to the check, Grantham was reached 4.5 minutes late, of which more than half had to be attributed to station « overtime » at Peterborough.

On the return trip the Great Western engine took the 1.10 p. m. Leeds-King's Cross, leaving Grantham at the booked time of 3.7 p. m. The stiff 1 in 200 to Stoke summit was a 10.8 minutes' climb with a tare load again exceeding 450 tons — a notable performance with so heavy a load. Delay was again experienced between Stoke and Corby, to which can be attributed the two minutes late arrival at Peterborough, in spite of some fast running beyond Essendine, touching 78 miles per hour near Tallington. At Huntington the train was still two minutes behind schedule, but at Hitchin one minute had been made up. An unhindered entry into King's Cross enabled the run to be completed half minute ahead of booked time.

It is now necessary to consider other developments, and pride of place may be given to a run with the King's Cross-Edinburgh Pullman car express working on the schedule which became operative on 21 September 1925, including a non-stop run from London to Harrogate. The Edinburgh train was worked by one of the well known Great Northern *Atlantics*, No. 3274. The start was easy, but through the tunnels the engine was inclined to slip, so that 7.2 minutes were taken to pass Finsbury Park at about 30 miles per hour. Running thence to Potter's Bar summit was, however, quite

good, the 10.2 miles occupying 12.5 minutes. Then came some very fine running, Hitchin being passed in 18.7 minutes (19.2 miles), Huntingdon (46.2 miles) in 40.3 minutes, and Peterborough passed slowly in 59.9 minutes (63.7 miles) from passing Potter's Bar, so that the 76.4 miles from London had occupied 79.5 minutes. The 23.7 miles, largely on ascending grades, to Stoke box were run in 26.7 minutes, and Grantham passed in 111.3 minutes from London (105.5 miles). The 14.6 miles to Newark occupied 13.6 minutes; the 18.5 miles to Retford were run in 20.3 minutes; and to Doncaster, after a long easing from Rossington and through the station at a bare 30 miles per hour, the 17.4 miles took 17.4 minutes. The 156 miles from London had thus been covered, without any sensational maximum speeds, in 161.6 minutes. The remainder of the route to Harrogate is necessarily complicated by checks for junctions and curves, so that a high average speed is impracticable, though No. 3274 did good work wherever possible. Eventurally the 198.4 miles from London were completed in barely 220 minutes, or 3 minutes under booked time.

For the next stage a *Pacific* locomotive was attached, No. 2578, though the route continues for some time to be unsuitable for high average speed bookings. The start to stop run of 11.5 miles to Ripon occupied barely 14 minutes, and, with several checks, the 13.7 miles to Northallerton (pass) were run in 18.6 minutes. Thence to Darlington running was spoilt by severe checks, so that the remaining 14 miles took 19.7 minutes. Leaving again, Durham was passed in 29 minutes from Darlington (22 miles), and the 14 miles to Newcastle took 18.5 minutes. At Newcastle, No. 720, one of the first three-cylinder 4-4-2's was attached, and, with allowance for the severe gradients in places and the occasional checks for curves, did good work in running the 67 miles to Berwick in 79.7 minutes. Starting again, Grants House (16.3 miles) was passed in 26.2 minutes, and the summit tunnel was entered 2 minutes later. Down Cockburnspath bank speed had to be occasionally checked, but eventually Waverley (Edinburgh) was reached in 74.4 minutes from Berwick (57.5 miles), so that the arrival, notwithstanding delays on the Ripon-Darlington stage, was a bare half-minute late.

Next in interest is the work of Midland type three-cylinder compound 4-4-0's, firstly on their own line, but principally on other sections of the London Midland & Scottish Railway, where their appearance is an innovation due to grouping. In this connection a journey via the Midland and Glasgow & South Western route from London (St. Pancras) to Glasgow may be first described. From London to Leeds one of the earlier standard engines of the class was used, No. 1029, the load being about 240 tons and the weather conditions fair. The train was assisted at the start, as usual, by the engine which had brought in the empty coaches, but only for the length of the station. The more or less adverse 30.2 miles to passing Luton were covered in 35.9 minutes. The next 11.6 miles (easy) were run in 10.3 minutes, but a bad check beyond caused the 49.9 miles from London to Bedford (passed at speed) to take 54.8 minutes. Thence to Wellingborough 15.3 miles were run in 15.4 minutes, and the next 4.9 miles to Kettering (long slack) occupied 8 minutes. Several speed reductions occur in the 27.1 miles to Leicester, while gradients are in places adverse, but the time occupied was barely 30 minutes, with an easy run in. From

Leicester to Leeds, whatever the route taken, involves many slacks for curves and junctions, so that good work was done to cover the 98.7 miles in 131.9 minutes, including one station and one signal stop, though there is no need to consider this stage in detail.

With a load of 220 tons, one of the new engines of the same general class, No. 1073, did good work over the hard route between Leeds and Carlisle. Practically all the way to Hellifield (36.2 miles) is complicated by curve, junction and other checks, so that this stage took 45 minutes. Onwards to Blea Moor summit involves severe climbing, the 17.3 miles taking 24.3 minutes. Thence to a stop at Appleby the 28.7 miles were run in 29.4 minutes. Starting again, the 28.1 miles to passing Scotby occupied 29 minutes, though signal delays caused the remaining 2.7 miles to Carlisle to take 6 minutes.

For the Scottish stage, again with a load of 240 tons, another of the new engines was used, No. 1065, but operating on what used to be the Glasgow & South Western Railway. The first stage was from Carlisle to Dumfries, the 33 miles of undulating route being covered in 37.3 minutes, start to stop. Then follows a long climb practically all the way to New Cumnock, but these 37 miles were completed in 45.4 minutes, a really good time. The remaining 21.2 miles to Kilmarnock, though generally easy, included a signal stop and the slow passage of a tunnel under reconstruction, so that they took 33 minutes. Here a Glasgow & South Western 4-6-0, No. 14673, replaced No. 1065, climbing the very steep grade at the commencement in good style, and with the usual checks approaching Glasgow reached St. Enoch station in 34.2 minutes (24.1 miles).

With one of the London expresses from Glasgow (Central) station, another Midland type compound 4-4-0, No. 1067, commenced with a moderate load of about 240 tons, but as the route practically all the way to Symington (where a stop was made to attach the Edinburgh portion) is punctuated with colliery slacks, checks for curves and junctions and other hindrances, it will be sufficient to mention that this stage of 35.4 miles was covered in 50 minutes. With the load increased to 335 tons, unassisted, No. 1067 was delayed somewhat during the very hard climb of 17.2 miles to Beattock Summit, which took 26.2 minutes. Down the famous bank speed was kept steady by frequent brake applications, the 10 miles occupying exactly 10 minutes. Passing Beattock at speed the 31.1 miles to passing Gretna were covered in 28 minutes, though delays over the remaining 8.6 miles to Carlisle caused the 39.7 miles from Beattock (pass) to take 42.1 minutes.

One other run on the London Midland & Scottish lines in Scotland may be mentioned, though the engine was a Caledonian 4-4-0, No. 14488, with a load of 220 tons. On the route concerned there are junction and curve restrictions, while gradients are frequently too severely adverse to permit of exceptionally fast times, but Larbert, 22.3 miles from Glasgow, was passed in 32.3 minutes, and Stirling, another 8 miles, 11 minutes later. Thence to a stop at Gleneagles, mainly climbing, the 17.2 miles took 25.4 minutes. To Perth the start to stop run of 16.7 miles took 20.2 minutes.

To complete reference to locomotive performance on the London Midland & Scottish Railway a return journey from Carlisle to London, in two stages, may be briefly described.

A London & North Western *Claugh-*

ton, No. 110, *Lady Godiva*, had a comparatively light load of 240 tons only from Carlisle to Preston. The first 17.8 miles to Penrith, start to stop, took 28.5 minutes, an easy time allowing for the unfavourable gradients. Starting again, the hard 13.5 miles to Shap Summit occupied 22.3 minutes, but afterwards some very fine running was made, the 58.7 miles to a stop at Preston taking exactly 58 minutes, with a bad check near Lancaster.

The next day a similar engine No. 23 (unnamed) had 320 tons to work through to London. The first stage to Crewe is not usually taken very fast, but the 51 miles, with two checks, were run in 64.4 minutes. Starting again, Stafford (24.5 miles) was passed in 30.7 minutes; the 36.5 miles thence to passing Nuneaton (check approaching) took 40.5 minutes, and the 14.3 miles to Rugby (stop) occupied 16.9 minutes. Thence to a signal stop, following a check, at Blisworth, the 20.4 miles took 27.5 minutes. The 16.1 miles to passing Bletchley occupied 19.1 minutes, the 15 miles climb to Tring 16.3 minutes, and the 26.3 miles, more or less easy, to Willesden Junction (passed at speed) took 25.8 minutes, the concluding 5 miles to Euston, with the usual slow descent of Camden Bank, accounting for a further 9.8 minutes.

Dealing further with the London & North Eastern Railway, the reference already made to a journey with the accelerated *Edinburgh Pullman* express may be completed by mention of several experiences on individual stages. Sir Vincent Raven's first three-cylinder 4-6-2 engine, No. 2400, *City of York*, had a load of 420 tons to work from Newcastle to York. The first 14 miles to Durham took 22.3 minutes, this being a stage where exceptional running is never made. The same remark applies also to the 22 miles to a stop at Darlington, which took 28.5 minutes. Thence the 21.9 miles to passing Thirsk took 25.8 minutes, and the remaining 22.2 miles to a stop at York, 22.5 minutes, so that the 44.1 miles from Darlington to York, with a very big load, had occupied 48.3 minutes.

On the very difficult « Waverley » route of the North British section, a 4-4-2, No. 9880, *Tweeddale*, was assisted to Galashiels, the load being about 320 tons and therefore over the maximum for one engine. There was, therefore, no special merit in completing the first stage to Galashiels (33.5 miles) in 49.6 minutes, though the route is a very hard one. The Galashiels-Melrose and Melrose-Hawick stages were covered, start to stop, respectively, in 6.5 (3.7 miles) and 20.9 (15.6 miles) minutes. Thence the train was banked to Whitrope summit, the 10.9 miles taking 20.8 minutes (the gradient is mainly about 1 in 70), and the remaining 34.5 miles to Carlisle, including hold-in checks down the bank and one or two junction or curve slacks, took 42.1 minutes.

A similar engine, No. 9876, *Waverley*, worked a load of 280 tons without assistance, though the writer travelled only between Galashiels and Carlisle. Stops were made at both Melrose and St. Boswells. The run from the latter place to Hawick took 15.9 minutes (12.3 miles), start to stop. With the load reduced to 230 tons, No. 9876, was only given a banked start out of Hawick, and otherwise climbed unaided to Whitrope summit, 10.9 miles, passed in 22 minutes. Thence to a stop near Carlisle, the 33.2 miles were run in 37.7 minutes, with the usual restrictions. In the opposite direction, No. 9904, *Holyrood*, of the same class, with 180 tons, covered the 15.6 adverse miles

from Galashiels to Falahill summit in 24 minutes and, with usual restrictions, completed the 17.9 miles to Edinburgh in 22.7 minutes.

Principal interest in regard to the Edinburg-Glasgow section of the London & North Eastern Railway is due to the extending use of 4-4-0 locomotives of Great Central design, generally referred to as « improved directors », in that Great Central engines of the original design were mostly named after the directors of that company. The new engines, by the way, are named after characters in Sir Walter Scott's novels, and are, therefore, often somewhat peculiar. In this case, No. 6379, *Baron of Bradwardine*, was concerned, and the load was 230 tons on the 1.0 p. m. from Edinburgh (Waverley) to Glasgow. Leaving Haymarket, where a pick-up stop was made, Polmont (21.1 miles) was passed in 26.8 minutes, but beyond that station, also near Lenzie approaching the Glasgow area, slight checks were experienced, so that the 23.5 miles to passing Cowlairs at the usual slow speed, in view of the terrific down gradient (1 in 45) beyond, occupied 30 minutes. A careful descent of the bank completed the 46.1 miles from Haymarket to Glasgow (Queen Street) in 60.5 minutes, practically as booked.

Reference to experiences on the London & North Eastern Railway may be completed by a few remarks on work done on the Great Central section. One of the now fairly old 4-4-2 engines, No. 6091, with a load of 200 tons, in misty weather, completed the run of 38.2 miles from Sheffield to Nottingham in 52.1 minutes, this over a route where high speed is rarely practicable for more than short distances.

A 4-4-0, No. 5504, *Jutland*, with 240 tons, passed Loughborough, 13.6 miles, in 17 minutes, and then took 10.6 minutes for the 9.8 miles to a stop at Leicester. Starting afresh, No. 5504 passed Lutterworth in 17.1 minutes (13.1 miles, mainly climbing), and Woodford (20.9 miles) 23.5 minutes later. Thence to Grendon-Underwood Junction (22.3 miles) occupied 21.4 minutes, and Aylesbury was passed at reduced speed 8.3 minutes later (8.8 miles). Over the steep gradients of the route taken good work was done, and when speed was again reduced, for the Rickmansworth curve, 24.6 minutes had been occupied for the 20.8 miles. Thence to a signal stop at Neasden Junction the 12.3 miles took barely 15 minutes. Eventually, including the signal stop mentioned, the 103.1 miles from Leicester to London were completed in 117.5 minutes.

So far as the London & South Western section of the Southern Railway is concerned, although the *King Arthur* class locomotives are now so extensively employed for principal trains, the writer seemed generally to manage to travel when engines of other classes were used. Thus, on the 11.0 a. m. from Waterloo to Exeter the engine concerned was No. 746, of the *Urie* 4-6-0's, the load being the substantial one of about 340 tons. Notwithstanding this, however, the first 12.1 miles were covered in 16.5 minutes, and Woking (24.3 miles) passed in 29.9 minutes, while the next 23.4 miles to passing Basingstoke, by no means an easy stage, took barely 27 minutes. Thence to Andover, still not exactly easy, the 18.6 miles were run in barely 19 minutes, and the final run down to Salisbury, with a long slow approach, took 18.2 minutes (17.2 miles). The complete run of 83.5 miles from London had thus been completed in 92 minutes, with a considerable load.

With the load reduced to 300 tons, a similar engine, No. 744, passed Templecombe, 28.2 miles, in 36 minutes, this stage being far from easy, and passed the summit of the long climb at about 1 in 70, which concludes the next stage, 48.6 minutes later (41.3 miles). The remainder of the run to a stop outside Exeter (18.3 miles) occupied 20.3 minutes, so that the complete run of 87.8 miles had been covered in 105.1 minutes, over a route very difficult where the maintenance of high average speeds are concerned.

Returning, with a load of 320 tons, the engine was *King Arthur* itself, No. 453 (fig. 3, *c*), but not on one of the hardest schedules. The 12.2 miles to a stop at Sidmouth Junction took 20 minutes. Starting afresh, the summit was passed in 11.9 minutes (6.3 miles), and Seaton Junction reached 6 minutes later (5.5 miles). Another stop was made at Axminster, after which the stage of 22.1 miles to Yeovil Junction was completed in 28 minutes. Thence to Templecombe the 10.5 miles took 16.5 minutes, start to stop, and the final stage, also start to stop, to Salisbury (with a check approaching) occupied 31.1 minutes (28.2 miles).

At Salisbury a 30-year old engine of a very peculiar class was attached. This was No. 720, a 4-4-0 locomotive having its driving wheels uncoupled, each being driven by its own pair of cylinders. There are six only of these engines, but they have several times figured in records given in these articles in the past, though it is remarkable, with so many new 4-6-0 engines available, to find one of them still on first class work. No. 720 was somewhat handicapped on the first and difficult stage, but reached Andover Junction in 29 minutes (17.2 miles). Thence to Basingstoke the 18.6 miles, start to stop, took 28 minutes. From Basingstoke to Woking, again start to stop, the 23.4 miles were covered in 27.1 minutes, and the next 9.3 miles to a signal stop at Hampton Court Junction took 14 minutes. The remainder of the journey to London, in view of delaying influences, calls for no comment.

Finally, two or three runs on the Brighton section of the Southern Railway may be briefly outlined. A 4-4-2, No. 422, with 290 tons, was checked on the earlier stages, so that 18.7 minutes were taken to pass East Croydon, 10.8 miles from Victoria. Thence to Haywards Heath the 27.4 miles were covered in 29 minutes, and the final 12.3 miles into Brighton, with a check approaching occupied 13.7 minutes. Returning, one of the big 4-6-2 express tank engines, No. 326, *Bessborough*, had the same load. It passed Haywards Heath, a difficult stage, in 16.6 minutes (12.3 miles), and covered the 27.4 miles to East Croydon in 36.1 minutes. The final stage was spoiled by signal delays near the end.

On the Eastbourne route one of the new 2-6-4 express tank engines, No. 799, *River Test*, (*k*) had a load of 270 tons to Lewes. East Croydon was passed in 17.6 minutes, and the 27.4 miles to passing Haywards Heath were covered in 32.1 minutes. Thence, with usual slacks, the 12.3 miles to the first stop at Lewes took barely 16 minutes. With the load reduced to 200 tons, the 15.7 miles to Eastbourne occupied 20.1 minutes. Returning, with 200 tons, a 4-4-2 express tank engine, No. 22, passed Lewes in 22.1 minutes after leaving Eastbourne, Haywards Heath (12.3 miles) 17.4 minutes later, covered the 27.4 miles to East Croydon in 33.1 minutes, and, with checks, reached Victoria 19.6 minutes later (10.8 miles).

[625 .1 (.66)]

An account of the construction of the Kassala Railway, Sudan,

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Figs. 1 to 10, pp. 93 to 102.

(*Journal of the Permanent Way Institution.*)

One of the main objects of building this line was to render possible the expansion of the cotton-growing area in the delta of the river Gash which is capable of very considerable development, in addition to which it will also open up the Eastern Sudan for the export of cereals, cattle, etc.

The river Gash is a flood river which rises in the Abyssinian hills and drains a mountainous country of heavy but spasmodic rainfall. It flows on the average for about seventy-five days in the months of July, August and September, and its waters are very heavily laden with rich silt.

The acreage which can eventually be brought under regular cotton cultivation is governed by irrigation possibilities, but by means of simple training works, to regulate the flow of the river, it is anticipated that within a few years after the opening of the railway about 70 000 acres of cotton will be grown annually.

The lines run South from the new junction at Haiya, between Thamiam and Einha on the Atbara-Port Sudan Line. The northern section comprising the first 115 miles passes through rough, hilly country cut up by many khorx (rivers) which are dry except during the two or three months rainfall. The Southern section of the line runs along the plains of the Gash Delta on an average gradient of + 0.06 % to the Western bank of the Gash opposite Kassala.

The maximum gradient is 0.66 % and sharpest curves 3°, of which there are only three, the others being all of 2° or less. The line is of 3 ft. 6 in. gauge, single track and laid with 50 lb. per yard New S. G. R. section rails.

Just beyond the tenth mile are two cuttings each about 1 600 feet in length with a maximum depth of 7 ft 6 in., but both of which were excepted from the surface and surrounding formation, to be composed largely of granite. It had therefore been decided to construct the first ten miles of the line before the rains, which may usually be expected from the latter end of July to about the middle of September, and to get a party out as early as possible to the cutting and, if communication could be maintained for watering and rationing, to keep them there at work during the rains, so that all the rock excavation and blasting work would be completed before the commencement of the construction in October, which was planned to be carried out at the rate of one mile a day on timber sleepers and at the rate of one and a half miles a day on steel peapod sleepers, the latter being used on

the second half of the construction through the part of the country most infested with white ants.

There are 17 stations in all, including the junction at Haiya and terminal station at Kassala, spaced at intervals varying between 11 and 20 miles. The intermediate stations are all of one standard layout comprising double main line tracks 1 400 feet long and a goods loop on the West side on which the station buildings and tukls are situated. The main line tracks are laid at each end with a split turnout and 1 in 12 crossing, to afford an easy run into the station.

The final survey was carried out during February and March, 1923, the whole length of approximately 200 miles of survey being effected at the average rate of 4 1/2 miles a day.

Work on the new junction at Haiya was started on 6 March, 1923, when a construction camp was formed at the junction site; the preliminary labour force consisting of about 150 Egyptian soldiers, of the Railway Labour Battalion, for carrying out the earthwork. The water for this camp was supplied twice a week by train from Thamiam, a supply of ground tanks being placed alongside the main line for the reception and storage of the water.

The lay-out at the junction comprises a double main line through the station of 1 400 feet from stock rail joint to stock rail joint. On the North side, a goods loop of 800 feet clear; a dead end 900 feet long alongside which was the bridging stacking ground; and a triangle for turning engines. On the South side two marshalling sidings for dealing with the arrival and despatch of materials for railhead; four sidings of 1 500 feet each running through the main stacking ground for permanent way materials; a dead end of 900 feet length for shunting trains to and from the main stacking ground and alongside which a stacking ground was formed for the reception of telegraph materials and materials and machinery in connection with water boring. A short siding, capable of accommodating 6 wagons was also laid close to the site of the Station Buildings for dealing with all building materials. This work, with the exception of the double main line tracks and the goods loop, being of a temporary nature only was laid with second-hand materials.

During March, April and May the earthwork and tracklaying for the junction were completed, 19 trains of permanent way, bridging and telegraph materials had been received, unloaded and stacked; 2.80 miles of the embankment had been constructed, the latter including five diversions for bridges. Bridge No. 1, comprising two 15 foot spans, and a culvert of three 2-foot pipes had been completed and a start had been made on the station buildings and tukls : circular buildings with conical roofs similar to the mud-brick or reed huts used by the natives of the Sudan, and provided in this case for the accommodation of the station staff and permanent way gang.

The labour force, which had been augmented from time to time, was composed, at the beginning of June, of :

320 Egyptian soldiers, of the Railway Labour Battalion.

64 Berberines for platelaying.

110 Berberine labourers, of whom about 30 were employed as labourers for the buildings.

6 masons. Mainly Egyptians of Upper Egypt.

The soldiers were utilised exclusively on unloading and stacking materials and on earthwork.

Railhead construction (tracklaying) was started on the 7 June, by which date 3.75 miles of bank had been completed and the transport of labour and water to the site of that work was becoming extremely difficult. Owing to the shortage of labour it was decided to carry out two or three days tracklaying only at a time and then for the same gangs of men to do the lifting and packing and filling

Fig. 1. — Railhead. — Laying out sleepers.

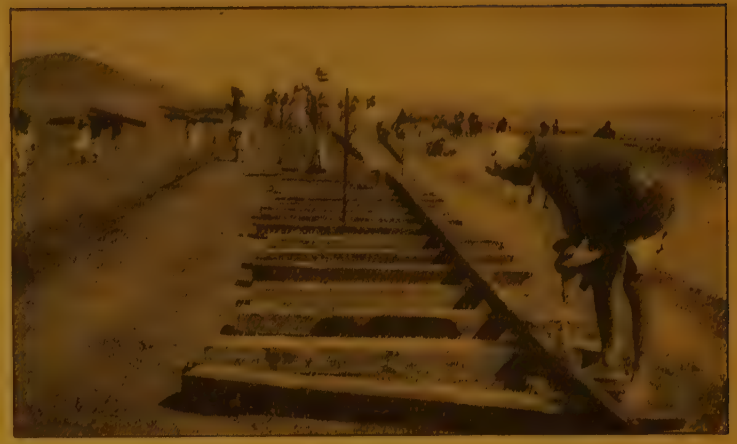

Fig. 2. — Railhead. — Fishing up leading rail.

Fig. 3. — General view at Railhead.

Fig. 4. — Bridge over Khor Delai-Km. 122 1/2. Three spans of 105 feet.

in on the following days. By this means the first four miles were laid and completed by the 19 June, when the construction camp was moved forward from the junction to railhead.

The labour organisation for railhead construction on this basis is shown in table I. This party laid 0.86 mile (150 rail lengths) of track on steel sleepers per diem, and lifted and packed and filled in the same length as another day's task.

TABLE I.

Labour organisation for laying 1 1/2 km. (0.93 mile) of single track with steel sleepers.

	Soldiers.		Civilians.
	N. C. Os.	Men.	
Carrying rails. Four parties of eight men and two men on each truck for unloading	2	36	...
Carrying sleepers	...	...	60
Carrying fishplates	...	...	2
Carrying fishbolts	...	...	2
Carrying steel keys	...	...	2
Laying 1st rail and attaching sleepers thereto	...	...	11
Laying 2nd rail	...	...	10
Fishbolt spanner boys, putting in two bolts per joint only.	...	...	8
With slewing bars adjusting expansion and lifting rail for fishing up when required	...	...	2
With slewing bars maintaining alignment of leading rail	...	...	3 (*)
Keying up (includes two men with bars for lifting up sleepers when required)	...	...	12
Measuring rails (with steel tape)	...	...	2
Marking off rail centres	...	...	1
Checking squareness of joints	...	...	1
Marking off sleeper positions and squaring off to opposite side	...	...	2
Slewing track to correct alignment in front of train	...	3	1 (*)
Water carriers	...	1	2
Following up train to collect any small parts, etc. left behind	...	...	1
	2	40	122

(*) Includes 1 Osta. A native, and equivalent to a leading ganger.

Tasks for other works were as follows:

Earthwork	Soldiers	4 cubic yards per diem normal task, but on bankwork were given six yards per man with extra pay for each yard above four.
Earthwork	Civilians (Berberines)	3 cubic yards per man per diem.
Unloading and stacking	Soldiers	
Materials :		
Rails (30 feet, 50 lb. section)		15 rails per man.
Steel sleepers		200 sleepers per man.
Jarrah wood sleepers		160 sleepers per man.
Points and crossings, bridgework, small parts, etc.		Dependent on facility of handling, etc., but allotted as far as practicable on basis of four tons per man per day.
Collecting ballast	Berberines	1 1/3 cubic yards per man per day.
Bricklaying		400 bricks per day in plain brickwork

By 28 June railhead had reached 6.5 miles and a party consisting of 1 foreman (Greek), 30 civilian labourers, accustomed to rock drilling and blasting work, and 50 soldiers has been established at the tenth mile and started work on the cuttings.

On 17 July railhead reached mile 9 and the construction camp was moved forward to railhead. The next few days were occupied in lifting and packing and filling in, followed by five days holiday for Bairam, at the end of which the rains set in and the construction camp was cut off owing to the washing out of the line at bridge diversions, of which there were 13 in that section, including two of each over three quarters of a mile in length.

The section was repaired again by the afternoon of 1 August, after five days work, and a train carrying water and rations was run through to railhead to supply the camp there and the party at mile 10. On that same night further heavy rains fell resulting in all the bridge diversions being again washed out and some considerable damage being done to other parts of the section, and extensive washouts occurred also on the main lines Atbara-Port Sudan and Atbara-Halfa, which latter necessitated the abandonement of the Kassala line for the time being as all available labour was urgently required for repairing the main lines.

Railhead camp was therefore withdrawn to Haiya Junction, the men returning on foot and their tents and baggage being conveyed, as far as possible, by camels. The party at mile 10 were left to carry on the work there and arrangements made for their water and rations to be transported from Haiya Junction by camels. This was most fortunately rendered practicable owing to the fact that the anticipated quantity of rock was not encountered in the cuttings and the party sent there in the first instance was sufficient to complete the whole of the excavation by the required time.

Owing to the extent of the washouts on the main lines no labour was available for repair work and continuation of the construction of the Kassala line until the 20 August, when a week was spent in repairing the damages and further construction was resumed as more labour became available.

By the end of September the line had been laid to 10 3/4 miles, which had been elected as the site for the construction camp, and a siding had been laid in there for the accommodation of trucks of stores, etc. Bankhead was then at mile 14, about three miles ahead of railhead, which was the initial lead reckoned on so that bankhead could maintain a sufficient lead on railhead allowing a margin for slower progress on high banks.

During the latter part of September

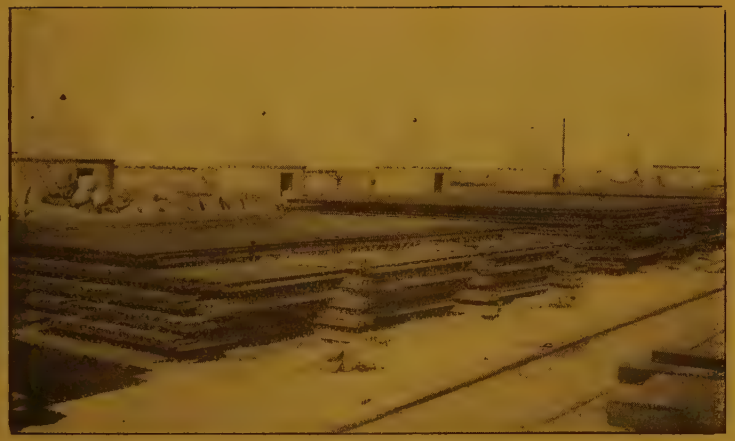

Fig. 5. — Rail stacked at Haiya Junction Base.

Fig. 6. — Jarrah wood sleepers at Haiya Junction Base.

Fig. 7. — Bankhead construction.

Fig. 8. — Camels taking water to Bankhead.

TABLE II.

Labour organisation for laying 1 1/2 miles (= 2.41 km.) of single track with steel sleepers.

	Soldiers.		Civilians.	
	N. C. Os.	Men.	Saidies.	Berberine.
In front of train.				
Carrying rails	3	75	...	...
Carrying sleepers	3	88	...	...
Carrying fishbolts and keys	...	...	...	6
Carrying and laying out fishplates	...	...	...	7
Laying out sleepers	...	...	...	5
Laying in first rail and attaching sleepers thereto	1	10	...	...
Laying in second rail	...	...	...	12
Fishbolt spanner boys. Putting in 2 bolts per joint only	...	...	...	17
With slewing bars adjusting expansion and lifting rail for fishing up	...	4	...	2
With slewing bars maintaining alignment of leading	...	...	...	3 (*)
Keying up (alternate sleepers only)	...	...	...	35
Measuring rails with steel tape	1	1	...	...
Marking sleeper spacing and squaring and marking rail centres	...	...	...	4
Slewing track to correct alignment in front of train	...	..	...	3 (*)
Water carriers	...	...	...	4
Behind train.				
Carrying fishplates and keys	...	...	...	4
Fishbolt spanner boys adding third and fourth fishbolts and tightening up	...	...	...	12
Keying up alternate sleepers not done in front of train.	...	...	...	12
Slewing track to correct alignment.	...	...	...	7 (*)
Gauge and keying hammer	...	...	...	2
Pinching out keys	...	...	...	4
Water carriers	...	...	...	2
First lift.				
Lifting jacks (3 per jack)	...	...	...	24
Pass packing	...	...	...	25
Beater packing	...	...	...	60
Packing test sticks	...	...	...	2
Supplying earth to packers	...	...	64	...
Slewing track to correct alignment	...	6	...	1 (*)
Filling behind packers	3	...	121	...
Miscellaneous.				
Survey party for centre pegs and level pegs	...	...	...	6
Sheikhs in charge civilians	...	...	...	11
Nobatchis (cooks)	...	...	...	9
Camp duties	...	...	...	7
Carpenter (for repairing tools, etc.)	...	...	...	1
Drilling and cutting rails	...	...	...	3
Putting in km. posts, tangent posts, etc.	...	...	...	2
Cleaning up, collecting old earthwork baskets, etc.	...	...	...	1
Allowance for absent, sick, etc.	...	...	...	25
	11	189	185	317

(*) Includes 1 Osta. A native, and equivalent to a leading ganger.

the necessary labour had been drafted to Haiya, consisting of Sudanese for platelaying, etc., and Saidis (Egyptians of Upper Egypt) for earthwork.

Diagram I (fig. 9) indicates the distribution of staff and labour at bankhead and railhead during the construction of the northern section with track laid on timber sleepers.

The supervisory staff at bankhead consisted of two British engineers, one Egyptian staff officer, two native surveyors and one native overseer. The labourers employed were Saidis, numbering 1 700 divided into gangs of fifty each under a Saidi Sheikh.

The position of bankhead varied from one mile to three miles ahead of railhead. The latter distance was found to be inconveniently far ahead for purposes of water and food supply, but was dependent on the amount of bankwork entailed; the distance increased or diminished according to the height of embankment.

As far as possible the main line banks at diversions were constructed, gaps being left at bridge sites, but it was occasionally necessary to omit the main line banks in order that bankhead should keep ahead of railhead, and the engineer in charge of bankhead had to keep his programme carefully mapped out for several days in advance to ensure the necessary lead being maintained.

The railway alignment throughout was « pegged out » early in the year, but only located by station points a mile apart and at every change of direction. The bankhead engineers had to interpolate between these stations, set out curves and diversions, run their line of levels and work out all bankheights and quantities of earthwork.

All earthwork was done by task, which entailed a considerable amount of work each day allotting the correct cubic quantity of earthwork to each sheikh of fifty men, complicated by the varying heights of embankment in the undulating and broken country. On completion of the daily task the top of the bank was levelled by a native surveyor, before the men left the site of the work, to ensure the bank being true to height and gradient.

The supply of water to bankhead was one important feature of the daily routine and was effected by a string of 130 camels, each carrying two ten-gallon water tanks, which were filled from wheeled tanks forming part of the railhead train.

The bankhead party moved forward daily, and nightly pitched their moving camp a day's task nearer Kassala, whereas the railhead camp was located at the permanent stations and at the halfway point between stations, which generally entailed a camp move once a week.

The train carrying material for a mile of track was despatched daily from the base at Haiya in time to arrive at the station in rear of railhead camp early in the afternoon. A construction engine was stationed at railhead camp and worked the material train during the process of tracklaying. On completion of the day's work this engine ran the empty trucks back to the station in rear, took over the full train for next day's work and returned to camp ready to start out the following morning. The empty trucks were taken to Haiya base by the engine which brought up the full train.

All diversions were laid on steel sleepers, to facilitate easy removal and to avoid having to re-bore the Jarrah wood sleepers when lifted and re-laid consequently the composition of the material train in respect of sleepers and fastenings varied daily, depending on the amount of diversion work entailed, and necessitating special orders being made out on the base for each day's train.

The construction train left camp daily at such time as to admit of its arrival at railhead at peep o' dawn. The composition of this train is shown on diagram I., and it was marshalled as follows:

One 5 000 gallon water tank, engine tank, three trucks of rails, three trucks of sleepers, small parts truck, ration truck, dispensary, permanent way Inspec-

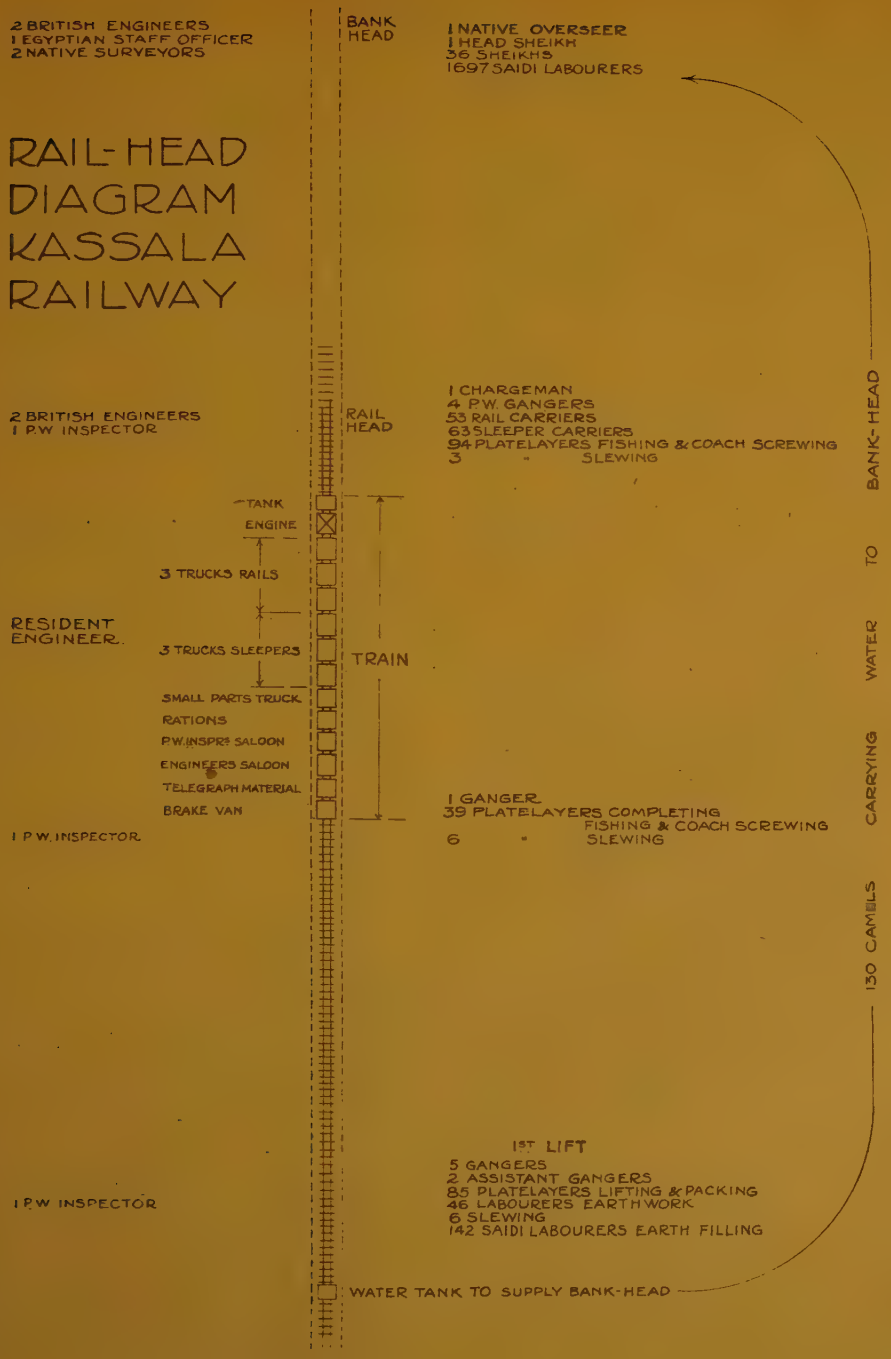

DIAGRAM 1.

Fig. 9.

tor's mess saloon, engineers' mess saloon, telegraph material, brake van and one 5 000 gallon water tank. On arrival at the point where the first lift party stopped work on the previous day the rear tank was knocked off, and from this tank the camels for bankhead drew their water until the train returned from the day's work. The first lift and earth-filling parties also drew their water during work from this tank.

A lead of 12 rail-lengths of rails and sleepers was always maintained in advance of the recorded completion of the day's work. The rails were fished up but not screwed down, thus enabling the coachscrewing gangs to commence operations immediately on arrival at the site of work without being delayed by having to wait for rails and sleepers to be unloaded and distributed.

The establishment in front of the train was as follows:

Two British engineers, one British permanent way inspector, one Egyptian staff officer, two native surveyors, one native chargeman, four native platelayer gangers and 215 labourers. The native surveyors worked ahead putting in centre line and level pegs every 100 feet on the top of the finished bank, setting out curves and putting in tangent posts and kilometre posts and fixing permanent bench marks at bridge sites.

The first operation in the tracklaying was the spreading of the sleepers and rails, which was done by Egyptian soldiers of the Railway Battalion. The sleeper carriers, 20 to each truck, moved forward on the right hand side of the track and threw the sleepers down on the bank. The sleepers were then turned to suit the boring and spaced by a party of five natives. The rail carriers, consisting of six squads of eight men per rail, moved forward on the left hand side of the track, placing the rails on top of the spaced sleepers. Six men distributed fishplates and fishbolts and the rails were fished up, only two bolts being put in per joint in the first instance and the expansion of the joints being adjusted at the same time with special gauges. Directly the joints were fished up the leading ganger slewed the rails to correct alignment and the joints were tested with a square. Before leaving the truck each rail was measured carefully with a steel tape, as the length varied as much as 3/8 ths of an inch either way, and it was therefore necessary for distribution to be made on either side of the track as occasion demanded to ensure the joints being kept square. The rail carrying squads always consisted of the same men under a leader who had to know the length of the rail his men were carrying and shout this out to the leading ganger on coming to the front so as to receive instructions as to which side of the track to place the rail. On curves the lead on the inner rail was adjusted by the insertion of special « white » rails 29 ft. 10 in. long; the normal rail being 30 feet. As soon as the rails were fished up the sleeper spacing was marked off with chalk and the centre of the rail also marked, the latter being required for squaring the joints owing to the track being laid with staggered joints throughout.

Eight gangs of seven men each (natives) were employed coach-screwing every alternate sleeper, each gang doing a rail length at a time. Two men levered up the sleeper with bars, four worked the box-spanners and the leader adjusted the gauge. Between the coach-screwers and the train the track was again slewed to correct alignment and when completed the train moved ahead, generally about three rail lengths at a time.

Behind the train the tracklaying party consisted of one permanent way inspector, one ganger and 45 labourers. The remaining two fishbolts per joint were put in and four coach-screwing gangs completed the fastening of the alternate sleepers. This done, the track was again slewed to correct alignment.

Two thousand feet behind railhead was the first lift party consisting of one permanent way inspector, five gangers, two assistant gangers, 85 native labourers lifting and packing, and 46 Saidi labourers supplying earth to the packers. The jack men lifted the track to the level pegs, putting on the required super-elevation on curves; the packing earth was then thrown in and the beater men packed the sleepers, doing three adjacent ones, and each sleeper being tested before the beater men moved forward to their next positions.

One of the best of the straightening gangers worked behind the packing, slewing the line to its correct and final alignment with the aid of a squad of six Egyptian soldiers with slewing bars. Following this party were 140 Saidi labourers earthfilling the track and trimming the edges and slopes of the bank.

A small party, known as « little first lift » used to start work in the morning at the beginning of the previous day's mile task, taking out any obvious slacks that might have occurred. This party generally caught up and joined the first lift proper about breakfast time.

In addition to their work in front of the train the two engineers supervised the first lift and filling, giving out the earthwork tasks for the latter.

On completion of the track-work for the day the water tank in front of the engine was left at railhead to supply bankhead, and the rear tank was taken back to camp. Next morning the construction engine had to run to railhead and bring back the empty tank before the construction train went out for the day's work.

Table II. shows the distribution of labour at railhead for the Southern section, where the track was laid on steel sleepers and at the rate of 1 1/2 miles a day.

A four-wire line of telegraph was constructed step by step with railhead, constant telegraph and telephone communication being maintained between railhead camp and the stations in rear and, on moving camp, communication was re-established within a few minutes of the arrival at the new camp site. A party of 25 linesmen and 25 Saidi labourers, for digging holes for the poles, were employed, under the supervision of a British telegraph inspector, for the execution of this work.

The whole of the railhead party, with the exception of earthwork labourers attached to the first lift, were encamped at the railhead camp, and comprised about 640 persons. An office staff, composed of one British clerck and five Native clerks, were employed in making out all pay-sheets and costing and all the numerous details of office work entailed in the undertaking. A large field bakery under an Egyptian officer with 50 soldiers supplied the whole of the establishment of about 3 000 labourers with bread daily. A well equipped hospital, under a British Medical Officer, was maintained and a dispensary truck formed part of the daily construction train. Other details of the camp organisation included the native storekeepers, carpenters, blacksmiths, tent-repairer, police and sanitary gang. A post office van, at which all postal business was transacted, and a canteen truck run by a contractor were established at this camp.

The second lift party worked about eight miles behind railhead and the third lift party about 30 to 40 miles behind railhead. Each of these parties consisted of one permanent way inspector, three gangers, four would-be gangers under training and 120 labourers. Their work was to-relift the track, bringing it true to line and grade and take out any slacks. Their task was one mile per day to keep pace with railhead.

One British engineer was in charge of the bridging, which was carried out by a contractor. As many as ten bridges were under construction at a time, in varying stages from excavation of the foundations to the erection of steelwork.

A British foreman of works was in

charge of the erection of station buildings. Two stations being in hand simultaneously.

To guard against the possibility of any breakdown of the daily material from Haiya base a complete train of permanent way materials and telegraph material and water supply for one day's work was kept stationed in reserve at the station immediately in rear of railhead.

As stated previously, construction commenced at 10 3/4 miles from the junction on 1 October 1923, and it was carried out at the rate of a mile a day up to the middle of February when the change over was made to steel sleepers and the daily task increased to 1 1/2 miles a day, this rate being maintained down to Kassala, which was reached by railhead on 21 April, 1924. Thus completing 213 1/2 miles of tracklaying in a total of 206 days, including all rest days and holidays, being an average of 1.23 miles per working day.

When bankhead reached the Southern section the labour force was considerably reduced owing to the bankwork being much lighter, the average height being 18 inches, and very few diversions for bridge sites were required. This section contains also a straight run of 80 1/4 miles, which considerably lessened the survey work at bankhead and combined with the fairly regular bank height enabled the supervisory staff to be reduced, and one engineer and the surplus labourers were sent back to Haiya to carry out the construction of the main line banks and the laying of the track over such bridges as had been constructed.

As soon as the bankhead work was completed, including the station and goods terminal at Kassala, the majority of the Saidi labourers were evacuated and returned to Egypt.

By 5 May a bi-weekly service of mixed passenger and goods trains had been inaugurated and the only construction parties remaining were a small platelaying gang finishing off the goods terminal at Kassala, the second and third lift parties, the bridging contractor and a party finishing off main line banks and putting the track across completed bridges.

Diagram II (fig. 10) is a sketch showing the route of the Kassala line and the proposed extension on to Sennar through Gadaref, and the eight photographs are representative of the work carried out.

Fig. 10. — Diagram II.

In conclusion the authors wish to express their thanks to Major P. C. Lord, O.B.E., late R.E., (Fellow), chief engineer Sudan Government Railways and Steamers, and to Mr. G. R. Storrar, M.B.E., assistant chief engineer and resident engineer on this construction, for the opportunity and facilities given in connection with the writing of this account, and also to Mr. H. D. Harvey for the photographs.

[625 .151 & 625 .154]

THE BRENNER STAR.

Arrangement of railway lines in the form of a star for turning locomotives.

Figs. 1 to 4, pp. 104 to 107.

(*Rivista tecnica delle ferrovie italiane.*)

The laying down of a large turntable, say, of 21 m. or 21.50 m. (69 feet or 70 1/2 feet) diameter, fully equipped with electric or compressed air motors, would cost today about 350 000 lire, for the structure, mechanism and foundations.

In face of this high cost, in comparison with pre-war prices, the Administration of the Italian State Railways considered a method for the turning of engines made up of a suitable arrangement of lines and points to take the place of turntables, and laid dow under certain suitable conditions in the neighbourhood of locomotive sheds, where it would not be possible, for want of space, to lay down the well-known triangle.

This arrangement, which we will describe as lines in star formation, and has proved more economical than turntables, was adopted for the first time on the Italian State Railways at the Brennero Station, and on account of the good results obtained will be extended to other stations in the near future.

Up till the occupation of the Haut-Adige, which followed the victory, the line from Innsbruck to Bolzano was worked without change of engines by the locomotives belonging to the South Austrian Railway (Südbahn). Since the occupation, however, and return to the train service over the Brenner pass, this line has been divided into two sections worked by two different administrations, namely, that of the South by the Italian State Railways, and that of the North by the Südbahn. The Brennero Station situated in Italian territory on the summit of the pass, and 1 370 m. (4 495 feet) above sea level, has become the joint station for the exchange of locomotives and rolling stock.

Whilst the station, which was enlarged at the opportune moment by the addition of new lines, was sufficient for working the trains, the necessary means for dealing with traction requirements was quite inadequate.

In the first place, it was necessary to provide for turning the locomotives, either in order to avoid the loss of time due to the reduction of speed allowed to engines working tender first, or in order to be able to make use of snow ploughs or protect the staff against the weather.

An old turntable was certainly in use at Brennero, but was quite insufficient for requirements of the service, being

Fig. 1. — General view of the lay-out of the star at Brenner.

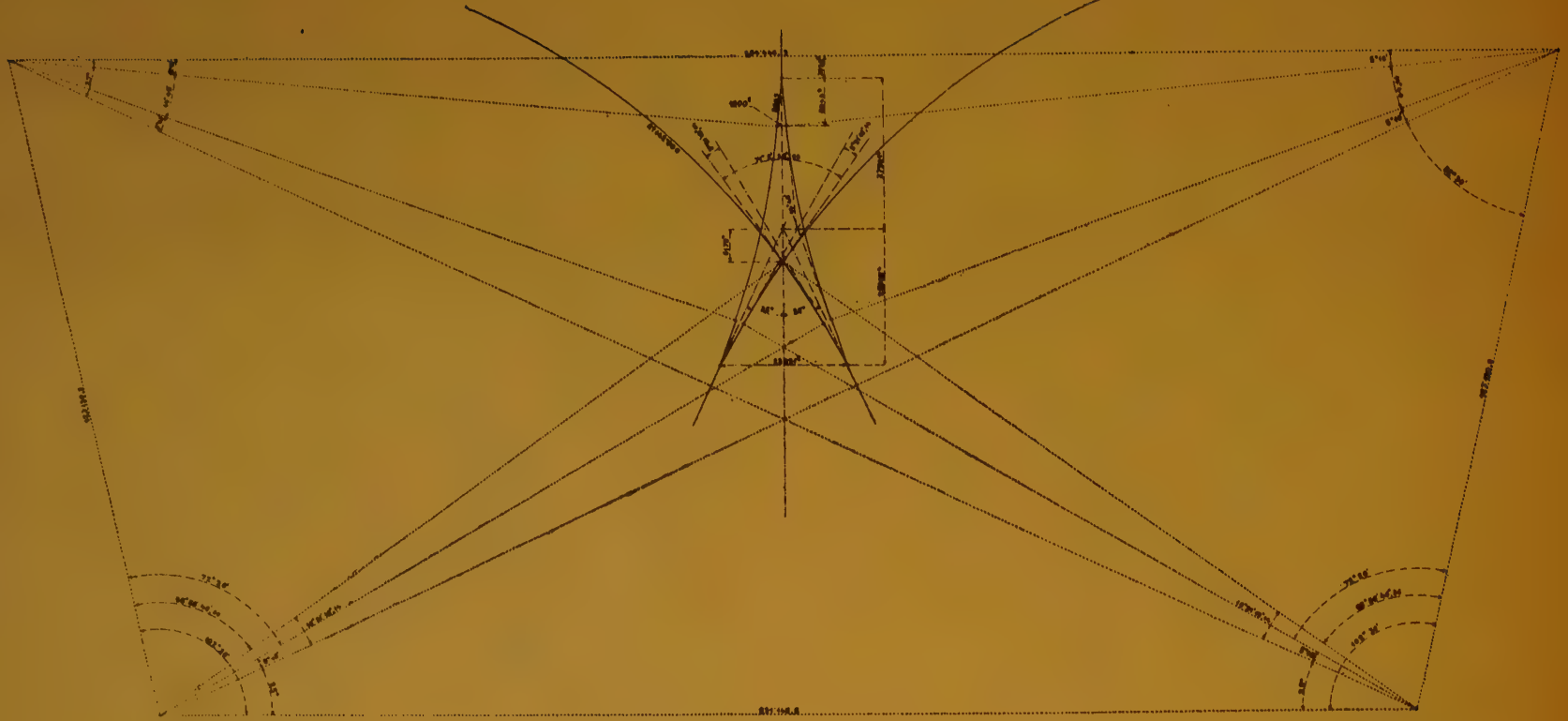

Fig. 2. — Geometrical lay-out of the star.

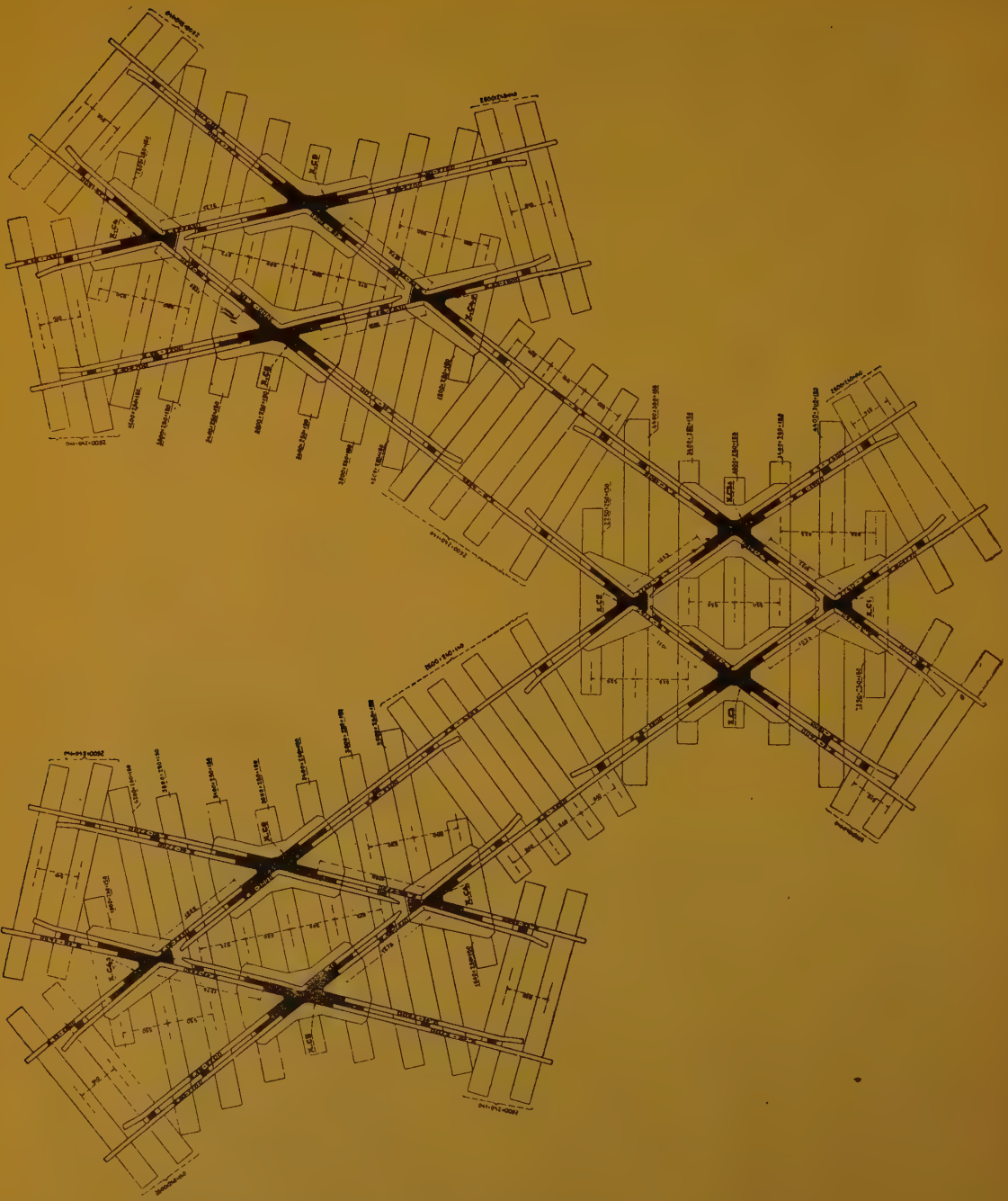

Fig. 3. — Plan view showing arrangement of crossings.

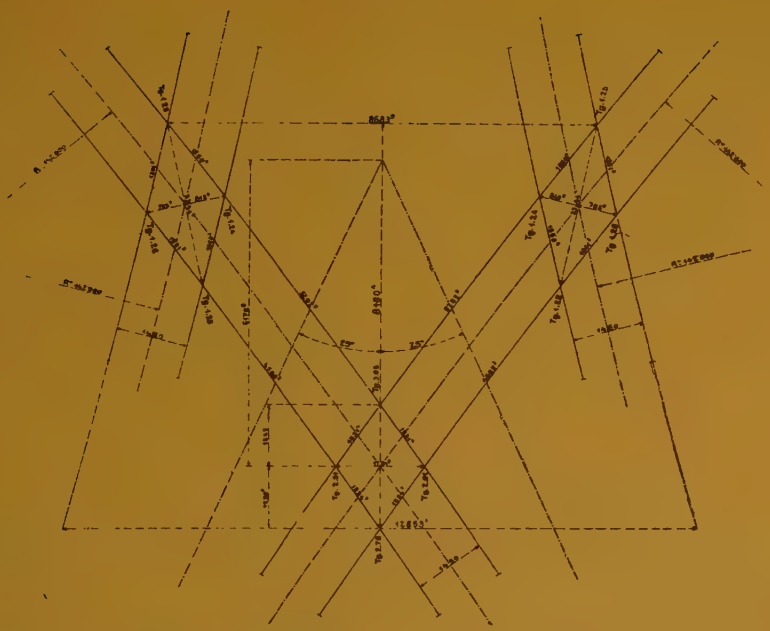

Fig. 4. — Geometrical lay-out of the crossings.

old and worn, and also because its diameter of 12.60 m. (41 ft. 4 in.) was too small for turning most of the Italian locomotives provided with tenders.

On the other hand, on account of expense, the fixing of a larger turntable was not advisable, for in the first place it would have had to be surrounded with a wind protector, and the turning of the table would have necessitated a couple of gangs of two men, because there was not a sufficient supply of electric energy at Brennero to work a sufficiently powerful motor, nor was there any possibility of using compressed air, as the Austrian locomotives which worked the service of trains beyond Brennero were fitted with the Hardy Vacuum Brake instead of the Westinghouse Brake.

The triangle method was also impossible for want of space, the only ground available at the northern extremity of the station and to the west of the railway being limited by the main road running alongside the line, beyond which comes the mountain range, leaving only a space of not more than 344 feet in width between the lines and the roadway, and was the only ground possible on which any turning arrangement could be fixed.

In face of the impossibility of constructing a triangle, a polygon in the form of a star was suggested, which, while taking up less ground space, would be sufficient to allow the locomotives to be turned.

Figure 1, which we reproduce, gives a general idea of the installation as put down, and shows after the addition of a few alterations and improvements the following characteristics : the minimum radius (see diagram fig. 2) is 142 m. (466 feet), and the rails are of the Vignole type X Südbahn, weighing 34 kgr. per lineal metre (68.5 lb. per yard).

The parts of the installation which necessitated the most care in design were the three curved crossings, which constituted the central portion of the star, and the three sets of points fixed at the ends of the lines to allow the necessary shunting to take place.

The three crossings are supplied with sharp and blunt crossing pieces in manganese steel, fixed on suitable supporting bed plates. The middle one is set to : tan. 3.05 $\frac{2.91}{2.91}$ 2.78, and the two end ones, which are perfectly symmetrical to one another, are set to tan. 1.26 $\frac{1.25}{1.25}$ 1.239.

On account of the high value of the tangent of these crossings, it was not possible to make use of rails of ordinary section, and for this reason cast steel was used, and in order to obtain a longer life, manganese steel.

The three systems of points at the ends of the main lines have been arranged so as to lie at the greatest possible angle to the radius of the curve of 142 m. (466 feet), which corresponds to the radius of the star.

The crossings from one road to another as used at the Brenner are arranged at an angle of 10° 20′ (tan. 0.18233), and to save time the standard points of the X Südbahn were used.

For this class of construction, however, a special arrangement of points has been designed, symmetrically laid down at tan. 0.20 on a curve, the radius of the outside rail of which is 150 m. (492 feet) and the length 16 m. (52 1/2 feet). The points are straight and 2 m. (6 1/2 feet) long, and the crossing pieces are fixed on suitable bed plates.

This minimum length of 16 m. (52 1/2 feet) has been adopted with the object of giving the least possible space to the point arrangement properly so called in the development of the star.

In principle, the smallest curve allowed for the passage of locomotives has a radius of 150 m. (492 feet) (and the laying out of the star arrangement at the different installations will be of exactly this radius), nevertheless on account of the limited space at their disposal, the radius of 142 m. (466 feet) has, as we have already pointed out, been exceptionally adopted at the Brenner.

In order to avoid employing men for working the points, instructions have been given that locomotives entering by the north extremity should always turn in the same direction, besides which the three systems of points in the star, as well as for the exit, have been made trailing by means of tie rods fitted with springs, which at the Brenner were afterwards replaced by an arrangement of counterweights because, especially in winter, ice made the proper working of springs uncertain.

It should be mentioned that as regards the capacity of the Brenner Star to cope with the work, the total length of the lines composing it amounts to about 500 m. (1 640 feet), and observation at different times proved that when one locomotive was being turned, others could follow on every four minutes.

Theoretically, therefore, it is possible to turn 360 locomotives in 24 hours, but normally the number of 60 is not exceeded at the Brenner.

Even with a turntable, though fitted with a motor arrangement, this rate of working cannot be improved upon if the time of running up and down the lines of approach to the table is taken into consideration.

The cost of laying down a star similar to the one described above is estimated to be about 180 000 lire.

As already pointed out, a turntable costs considerably more to put down, and necessitates far greater maintenance costs, besides involving serious delays in service, for the mechanism is very susceptible to failure; and a turntable,

even though fitted with a motor, requires at least one permanent attendant.

With the star arrangement the human element is eliminated, and the upkeep expenses are reduced to practically nothing.

The installation at the Brenner may be considered as representative of the star idea; for other stations the Administration of the Italian State Railways has already several similar plans under consideration, in each particular case introducing alterations that may be necessary to coincide with the amount of space available, and the run of the lines adacent to the engine sheds.

[625 .143.2 & 625 .143.3)]

Means of prolonging the life o ra [1].

(Railway Age.)

Assuming that the rail and the track have been well maintained, the question before this committee is to determine what else affects the life of rail and what can be done to prolong its life. Factors which enter into this question include the following :

1) The quality of the rails when new;
2) The handling of rails;
3) The correct laying of rails;
4) Chipped and battered end rails;
5) Defective and damaged rails;
6) Rust;
7) Worn joints.

Quality of the rail when new.

The effect which the quality of the rail has upon its life is well demonstrated by the condition of much rail which was manufactured many years ago, when compared with almost any rail which has been manufactured and laid in recent years.

The rails manufactured 30 or 40 years ago are still standing up without mashing and without battered joints, even though laid with 1/2 to 3/4 inch openings between rail ends. It would seem the part of wisdom to have chemical analysis made of samples of old rails which have given excellent service and to use similar chemistry in some test installations of rails made by modern methods and to modern dimensions.

Few people apparently realize how much damage can be done to rails by careless handling, but it is a fact that many rail failures are the result of careless unloading, a careless stroke of a spike maul, etc. For instance, on one road where all failed rails are held for inspection by a representative of the chief engineer, it has been found that in 75 % of the split web rails, where the crack is down in the middle of the web, or angling across the web, spike maul marks are to be found on the web, usually on the side opposite the beginning of the crack. Where blows from a spike maul in the web of a rail are so plainly a cause of failure there can be little doubt that similar blows on other parts of the rails also cause failures at times. The remedy is, of course, careful handling.

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(1) Report presented at the forty-third annual Convention of the Roadmasters and Maintenance Railway Association held at Kansas City in September 1925.

Correct laying of rails.

Next to the effect of the quality of the steel upon the life of rail, the manner of its laying in track probably has more to do with its life than any one other factor. By manner of laying of rails is meant :

A) Whether or not it is laid with proper space between rails to take care of their expansion in warm weather.

B) Whether or not the low ties are surfaced up promptly or shims used to prevent the bending or kinking of the new rails.

C) Whether the new rails are being anchored promptly to preserve the distribution of the expansion space.

D) Whether the proper jointing of the rails, lining of track, etc., is being done.

E) Whether the rails are canted inward so as to present a normal bearing of the head to the tread of the wheels, or whether they are laid with the axis of the rail vertical, regardless of the bearing of the wheels.

The first factor in the correct laying of rails is to provide sufficient space between the rail ends to take care of the expansion of the rails in warm weather. Naturally this is of the most importance when rails are laid in cold weather, and of less importance as the weather conditions, when the rail is being laid, approach the maximum temperature which the rail will have to undergo while in service.

The second factor bearing on the correct laying of rails, the prompt surfacing up of low ties, must be given careful attention to avoid damage to the rails by bending or kinking, in the same spots where the old rails were down.

The third factor, the prompt anchoring of rails in place, is necessary to prevent the rails creeping, with consequent bunching, causing tight joints at some localities and open joints at other places.

The fourth factor mentioned, which really is a grouping of several factors, covers the prompt and correct bolting up of joints, and doing other work necessary to put the newly laid rail in the best possible condition. The importance of providing for the expansion of the rails is shown by the fact that a rail 33 feet in length will increase 1/16 inch in length for each 25° of rise in temperature, and a rail 39 feet in length will increase 1/16 inch in length for each 20° increase in temperature, or in one mile the rails will increase 8.24 inches in total length.

Item E, that of canting the rails inward, is at least of equal importance to the necessity for providing for the expansion of the rails. Those opposing the use of canted tie plates and the resulting canting of rail, and consequently defending the laying of rail vertical are not defending an old and long established practice, as they seem to think, for, previous to the use of treated ties it was the general practice to cant the rail inward by adzing the ties enough to make the rail head show the wheel bearing in the center of its face.

With the advent of treated ties the adzing of ties was no longer good practice because of its damage to them and, to avoid damaging them by adzing, the practice of laying rail vertical was adopted for the protection of the ties and without any thought or consideration of the damage which it might do to the rails and the wheels. The practice was not the result of careful thought or well considered experiment, but, like Topsy, it « just growed ».

The results to the rails, of vertical laying are :

1. — The wearing and mashing down of the gage side of the rail head until the face of the rail approaches the line of taper of the wheel.

2. — The rolling out of a bead, or « hang over », along the gage edge of the rail head.

3. — Within the last five or six years a new type of rail failure has become noticeable, in the form of a crack in the web at, or very near, the line of connection of the fillet, under the head, with the top of the web. Investigations have made it quite evident that this kind of failure is due to eccentric loading of the rail.

4. — For several years past rails have been showing more and more results of wear in the shape of black « wear » spots along the gage edge of the face of the rail head. Their origin is so uniformly along the gage edge of the rail that it is evident that they are due to the concentration of the load there, due to the vertical position of the rail.

5. — Since the vertical laying of rail has become the common practice, the alinement of track has deteriorated very noticeably, and it requires only a test of canted tie plates to prove that the line of the rails is much better where they are canted inward than where laid vertical.

6. — The wear of the wheels due to contact with the rails is bound to be at the point of contact, and the depth of wear is governed by the width of bearing. With rails laid vertical, a new wheel must make contact with a new rail well toward the inside edge of the rail and near the flange side of the wheel. This must result in wearing a groove in the wheel deepest near the flange and not normal to the face of the wheel. If the rail is canted to the same extent as the taper of the wheel the bearing between the two is normal to each, and the wear more nearly preserves the taper of the wheel than will any other form of contact.

For these reasons it is necessary, if the greatest possible life is to be gotten out of rails, that they be laid canted to the same extent as the taper of the car wheels. To do this, and at the same time protect the ties, canted tie plates should be used.

Chipped and battered ends and defective and damaged rails.

Two causes are largely responsible for chipped and battered end rails. One is the quality of the rail itself, and the other is the laying of the rail too tight without sufficient space for expansion. Prior to the change in the chemistry of rail steel a battered end rail was found occasionally but the occasions were not frequent, as is proven on the many miles of the old rail still in tracks. On the other hand, rails of recent manufacture usually show battered ends within three or four years, and in many instances they have become so numerous that they compel the replacement of the rail at half the service which it should give, and would give except for them.

A great many of the battered end rails result from the chipping of the rail ends. And in almost every case of chipped end rails, the rails are either tightly together or have been tightly together, as is proved by the depression in the face of one rail end made by the overlap from the other rail end. The projecting metal rolled out from the head of a rail will not overlap the adjoining rail if there is any opening between them, but will turn downward between the rails. When the contraction of the rails in cold weather produces an opening between rails previously tight the overlap rolls downward, forming a projection beyond the part of the rail end lower down, and when hot weather again brings the rails tight, the pressure on this projection splits a chip out of the face of one or both rails, thus producing the chipped end and the beginning of a badly battered end rail.

Damaged rails are of numerous kinds, the most common being no doubt those damaged by spinning drivers. Other types are kinked rails, rails damaged by broken wheels, rails bent or twisted by wrecks, etc. Rails burned by spinning drivers are rarely burned deeply enough to do any damage unless the engine

drivers are allowed to run longer than necessary.

Remedies for damaged and defective rails.

While the preceding has dealt with the factors which affect the life of rails, and the prevention of such conditions, some remedies are available for prolonging the life of rails after they have become damaged.

The remedy which should be mentioned first is the building up by some welding process of rail ends which have become chipped or battered. This properly comes first because it is a remedy which can be applied to the rails in track as soon as the damage occurs. During the last half dozen years the practice of repairing battered rail ends by welding, either by gas or electric processes, has grown and is proving both successful and economical.

The building up of chipped and battered rail ends not only prolongs the life of the rail, but it reduces the cost of keeping the track in good surface, as it is difficult to keep the joint ties up where the joint is chipped or battered. It also helps to protect the ties from wear which would otherwise result from the pounding of the wheels over the bad rail ends.

Sawing off rail ends.

As the battering of rail ends becomes more frequent and troublesome it sometimes becomes necessary to remove rail from track « out of face » for this cause alone. In such cases the rails are generally in good serviceable condition except for a few inches at each end, and it is found desirable to have the worn ends of the rails sawed off and the rails redrilled, after which they frequently are suitable for reuse in the same class of track from which they were removed. This process is preferable to rerolling, because it preserves the fishing spaces of the rails unimpaired, which is not always the case with rerolling. It also preserves the hard face of the rail (the service temper) that has been produced by the cold rolling of the car wheels and which helps to resist further wear. This the rerolling process does not do. In addition, the resawing of the rails is much cheaper than rerolling.

When rails are being resawed the cut off should include the entire length of the joint bars, in order to remove the wear of the joint bars on the under side of the rail head, and thus give the joints a full and true bearing when the rails are relaid. New joint bars should be used in relaying resawed rail, for the old joints are usually more badly worn than the rail being removed.

Rerolling of rail.

For badly worn and battered rails, the first remedy to attract general attention was to send the rails to a rerolling mill and have them rerolled to a slightly smaller section. By this process the decrease in the size results in an increase in the length of the rail so that it is cut off to its original length.

In service the rerolled rails proved very erratic, giving satisfactory results in some cases and very unsatisfactory results in others. As a consequence, the rerolling of rail has practically been abandoned, except for rails which are curve worn, rails with badly roughened heads, rails which are twisted, and rails which are so badly bent or kinked that they cannot safely be straightened cold. For the reconditioning of such rails rerolling seems to be the only process available.

The sixth factor in life of rails as outlined above is rust. Near the sea coast, or bodies of salt water, and, perhaps more seriously on tracks which carry a considerable number of refrigerator cars in which salt is used to aid the cooling,

considerable damage is done to rail and track fastenings by rust.

A reasonably satisfactory remedy for this is found in the rail oilers, consisting of pneumatic machines which spray oil over the rails, below the face level as the machine is drawn along the track. The results of such oiling are reported to be very satisfactory and where the tendency to rust is very bad its benefits are found to be far greater than the cost.

Worn joints.

The seventh and last factor in the life of rail is worn joints, or more properly, joint bars. There is more wear of the joint bars and of the rails where the bars are in contact with them than is generally appreciated. In the case of the joint bars this is particularly aggravated directly under the ends of the rails. It frequently happens that after six or seven years in track the wear of the bars becomes so great that the rail ends begin to dip down at the joints in spite of all maintenance efforts. It then becomes advisable to replace the joints with new or repaired joints which do not have the worn faces.

A process has recently been developed to recondition the rail joints by heating them to a forging temperature and passing them through a forging press, thus restoring the bar to its original fishing fit, following which they are heat-treated. Only such joint bars as are of good material and of sufficiently high carbon to make the heat treatment effective should be selected for such reconditioning.

[625 .142 (.73) & 625 .173 (.73)]

Frisco studies various methods of making tie renewals,

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Fig. 1, p. 114.

(*Railway Engineering and Maintenance.*)

Commencing at the beginning of 1924, a series of experiments has been conducted on the Eastern division of the St. Louis San-Francisco with the object of reducing maintenance costs by the application of scientific methods and the education of employees in their use. Thus far, the work has been concentrated on a study of the situation prevailing prior to 1 July 1924, and on the application of new methods subsequent to that date, particularly in the installation of ties, as that operation consumes a large proportion of the maintenance appropriation.

Based on our experiences we can safely say that with an adequate engineering staff, properly trained, we can materially reduce all maintenance expenditures. In other words, we can obtain much greater efficiency in the handling of all maintenance work by the careful study and the scientific, practical application of better methods based on complete analyses. In the past, such matters have been left largely in the hands of roadmasters, who have neither the time nor the equipment to go into the scientific detail necessary to get high efficiency. The experiments thus far must be con-

sidered in the nature of a progress report with the object eventually of increasing efficiency in all departments of track work.

Fig. 1. — Tie renewal chart for 23 gangs giving number of ties inserted per man-hour, foreman's time included.

Based on daily reports

In order to make possible the study of costs, we found it necessary first to install a daily system of reports from track foremen in the field to provide the necessary data on current production and costs. This report system was described in an article by Carl P. Hoff, appearing on page 345 of *Railway Engineering and Maintenance* for September, 1925. Prior to the actual start of the experiments in tie installation, these reports were studied carefully and a fairly accurate set of costs was obtained.

For the last six months prior to starting this experiment, in other words, from 1 January, 1924, to 1 July, the cost of installing ties in chatts and gravel ballast on the Eastern division averaged 35.6 cents, or 41.5 cents in the terminals and 35.1 cents outside. The cost of inserting ties in July, the first month of our experiments, averaged 32.1 cents for the division or 47.3 cents in the terminals and 31.9 cents ouside. During August the cost was further reduced to 31.7 cents on the division as a whole or 38.8 cents in the terminals and 31.0 cents outside. During September the average cost was reduced to 29.8 cents for the division, 40.2 cents in the terminals and 28.8 cents outside.

No intensive effort has been made as yet to reduce the tie installation cost in the terminals. Our activities have been concentrated on the outside sections where the greatest saving can be accomplished in the shortest time. The experiments are being continued in 1925 and during this year we will give attention to the terminals and also to the branch lines and more of the sections where the ballast is gravel. Seven of the tests made last year were in gravel track while 16 were made in chatts. It is believed that we can reduce the averages considerably in both chatts and gravel during 1925 and lower the cost somewhat in the terminals by making an intensive study of the conditions.

It is interesting to note that the Eastern division has several large terminals. St. Louis, Neuwburg, Springfield and Monett, which hold up the average cost of tie installation in spite of reductions in the cost out on the line. Owing to certain fixed conditions costs are necessarily higher in terminals than out on the line. However, in spite of that fact, the average cost of tie installation during the month of August 1924, was 31.7 cents while the average cost on the system for applying ties in chatts or gravel ballast during the same month amounted to 33.3 cents.

Change in methods reduces costs.

A few individual cases showing the most marked changes will be of interest. For example, on one section under a first-class, competent roadmaster, we found from the daily cost data that the average cost of putting in ties was 44 cents. After applying proper methods

of installing the ties, but without any change whatever in the working conditions, this average cost dropped to 21.6 cents on the first day the test was made. The foreman in charge is an unusually hard worker, with excellent men of long experience, and yet the change in cost was very large owing to the fact that he had used a poor method of handling this work. This condition was found at many places.

In another case the section cost averaged 34 cents prior to the first test. On the first day's experiment, with the same working conditions, the cost fell to 19.9 cents. On another section, with good average men, ties were put in at a cost of 18.1 cents, which remains the record on the division to date.

It should be made clear that in all of these cases the men did not work unusually hard and were in no wise worn out or unusually tired at the end of the day's work. In fact, in one case (the first mentioned above) they said voluntarily that they had actually done less work and felt less tired than usual at quitting time. It is an interesting side-light to note that in practically all cases the foremen and men took a deep interest in the attempts to improve their methods and co-operated wholeheartedly.

In all of these experiments nothing but first-class work was done. There was no slighting of the work to gain speed. In all of the cases handled the track was left in perfect condition as regards line and surface and dressing up at the end of the day. Any picking up of low spots or lining necessary in connection with the installation of the ties was taken care of as usual and the ballast shoulder left completely dressed so that no return trip to the job was necessary. In connection with all these studies and experiments, every man was clearly impressed with the idea that only first-class work would be accepted and that while we were interested in reducing cost, as a matter of fact cost was secondary to firs-class work.

On the Eastern division, the conditions differ on different sections as regards the applying of ties, but as most of the work is done in either chatts or gravel, there is really a fairly comparable basis on which to work. Small-size gravel, fairly clean, differs little from chatts as far as the cost of tie renewals is concerned, but where very large gravel in encountered or where a great deal of mud has seeped up through the gravel, it is more expensive to install ties than in chatts or clean gravel of proper size.

Try to discover the best methods.

In making these practical experiments in the field, we started out with the idea of using not only our own methods, but also the best methods of every foreman. In that way we were able to determine the best methods of operation and to combine them into one complete practical method of applying ties, which would bring lower costs.

Therefore, in collecting the cost records, we worked out a large cost sheet on which the record of cost for each section was posted each month. After several months of this posting, the record showed clearly that certains sections were consistently running higher or lower in cost than others. A day was then spent in the field on each of these sections and the methods used by the high-cost foreman and by the low-cost foreman were studied in detail and charted form the stop watch data.

It was found that some of the variation in cost was due to variations in the methods observed by the formen in reporting the time charged to tie renewals. For instance, some foremen considered the tie insertion complete when the new tie had been pulled in, and charged part of the time to spiking, gaging, surfacing, or dressing the ballast shoulder. Another foreman arbitrarily reported one tie per man per hour at such points as street

or road crossings. Other foremen, when assisting other sections, reported all ties as put in by their own gang, the other foreman doing likewise, thus cutting the cost in two.

When ties are trucked short distances, on account of improper distribution, the time should be charged to tie insertion, but where the ties had not been distributed at all, as in terminals, and had to be trucked a considerable distance, this trucking was not charged against tie insertions. On account of the variety of ways of disposing of old ties, this time was exclused. This covers hauling away the ties, piling and burning them or splitting them into fence posts.

However, after all accounting adjustments of this kind were made with the co-operation of the accounting department, roadmasters and foremen, the costs were placed on a fair, comparable basis, the net result being a small raise in the average cost.

Make time studies.

Stop watch tests on different gangs, showing the exact movement of each individual, were then made in complete detail. We watched the methods of the men and combined, as stated before, the good features we found, finally arriving at a sort of standard method which we have since used with only small changes in all of these experiments. For purposes of information in this connection, a separate, sheet showing stop watch comparisons of different methods with different men under practically the same conditions, was compiled as shown in the table. These sheets show considerable variation in the several operations. Case 4 is really an experiment based on the conclusions arrived at by a study of cases 1, 2 and 3. Therefore, we will examine cases 1, 2, and 3 first.

« Pulling spikes: Two men pulling spikes at one tie get in each other's way and time is lost in case 3 by dropping shovels and picking up claw bars for each tie. From the time consumed per tie we may conclude that cases 1 and 2 do not have the best method. Of course, since the foreman's time is not charged in these stop watch experim nts, he will cut down the average time whenever he assists. This, however, would have no effect on the ultimate methods used as the foreman's time was taken into consideration and charged when the actual cost data were made up in all of these cases. We do believe, however, that in the future the foreman can assist to the best advantage if he is employed in a position where he can also supervise and we conclude, therefore, that case 2 has the best method.

« Digging out at side of old tie: Something is wrong with case 1. Upon examination we find that the two men are digging out much too deep. The foreman is not with these two men at any time and we conclude again that his time would be better spent here than ahead pulling spikes. We find also that the system of handling men in case 1 eliminates the competitive element. We conclude that case 3 has the best method.

« Pulling out old tie and inserting new ties: Exactly the same comment as applied above to case 1 holds here. Cases 2 and 3 used the same methods. We see that case 3 has lost the advantage gained in digging out—probably due to the distribution of the foreman's assistance.

« Tamping : On account of the way case 1 handles the plating and dressing these operations cannot well be separated. However, the total time spent on the three operations exceeds the total time used in cases 2 and 3 for the same work and we may conclude that the method in case 1 results in loss of time. We see that the best time is made when the foreman nips and both men tamp and conclude that case 2 has the best method.

« Similarly we continue through the remaining operations. We see that No. 3 gains time over No. 2 in spiking—probably due to the fore-

TABLE 1.

Stop-watch comparison of methods.

Pulling spikes.

1. No time charged. Foreman pulls all spikes.
2. 1.8 minutes per tie. One man goes ahead and pulls spikes.
3. 2.7 minutes per tie. Each two men pull their own spikes. Foreman assists.
4. 1.0 minute per tie. One man goes ahead and pulls spikes. Foreman assists.

Digging out at side of old tie.

1. 13.7 minutes per tie. First two men dig out for next two men.
2. 6.0 minutes per tie. Each two men dig out their own ties.
3. 5.5 minutes per tie. Each two men dig out their own ties. Foreman assists.
4. 6.0 minutes per tie. Each two men dig out their own ties.

Pull out old tie and insert new tie.

1. 8.2 minutes per tie. First two men pull out old tie and insert new tie for next two men.
2. 5.5 minutes per tie. Each two men do their own work. Foreman assists.
3. 6.0 minutes per tie. Each two men do their own work. Foreman assists.
4. 5.8 minutes per tie. Each two men do their own work. Foreman assists.

Tamping.

1. 13.5 minutes per tie including plating and dressing. Second two men assisted by foreman.
2. 4.8 minutes per tie. Each two men tamp their tie. Foreman nips.
3. 6.8 minutes per tie. One man nips and one man tamps. Foreman assists.
4. 3.9 minutes per tie. Each two men tamp their tie. Foreman assists.

Spiking.

1. 6.5 minutes per tie. Second two men spike for first two men.
2. 3.8 minutes per tie. Two men spike all ties near close of day.
3. 2.9 minutes per tie. Two men spike all ties near close of day, assisted by foreman.
4. 4.3 minutes per tie. Two men spike all ties near close of day.

Dressing up ballast.

1. See « Tamping ».
2. 3.3 minutes per tie. Two men and foreman near close of day.
3. 3.8 minutes per tie. Two men and foreman near close of day.
4. 3.9 minutes per tie. Two men and foreman near close of day.

Plating.

1. See « Tamping ».
2. 0.6 minute per tie. One man and foreman ahead of spikers.
3. No plates used.
4. 0.8 minute per tie. One man and foreman ahead of spikers.

Adzing.

1, 2, 3, and 4, foreman does all adzing.

Totals.

Case.	Test totals. Time consumed.	Totals for five months. Cost per tie.	Average cost per tie.	Number of ties inserted.
1	41.9 minutes per tie.	$0.320	$0.444	369
2	25.8 — —	0.203	0.230	339
3	27.7 — —	0.226	0.304	461
4	25.7 — —	0.194	0.444	369

man's assistance, but loses a part of it again in dressing up ballast. Also we must note that case 3 has no plates to apply. There is really little room for choice between the two methods for the remaining operations.

« Summing up, we conclude that the method in case 1 is entirely undesirable and No. 2 is best. This is borne out by the total time consumed per tie for the three sections. No. 3 loses time pulling spikes and tamping. »

TABLE 2.

Result of tie renewal tests during July, August and September 1924.

TEST.					Previous record 1 January to test.			Subsequent record test to 30 September.		
Section.	Kind of ballast.	No. of ties.	Total cost.	Average cost.	Ties.	Total cost.	Average cost.	Ties.	Total cost.	Average cost.
14	Gravel.	40	$10.86	0.271	723	$243.56	0.333	492	$155.92	0.316
16	Gravel.	22	7 24	0.329	766	293.17	0.383	224	86.00	0 383
23	Gravel.	37	12.22	0.330	1 277	485.91	0.381	408	113.49	0.278
31	Gravel.	31	10 93	0.353	353	139.62	0.396	269	84.02	0.312
31	Gravel.	40	10.43	0.260	558	205.01	0.368	64	18.31	0.287
34	Gravel.	41	13.12	0.320	334	107.44	0.322	41	13.12	0.320
35	Gravel.	60	13.86	0.231	225	78.98	0.351	60	13.86	0.231
37	Chatts.	38	8.14	0.214	486	158.74	0.327	156	35.95	0.230
40	Chatts.	70	17.04	0.243	705	238.48	0.338	232	74.55	0.321
42 1/2	Chatts.	60	10.86	0.181		None.		189	32.85	0.174
44	Chatts.	38	7.69	0.202	522	162.75	0.312	285	78.13	0.274
49	Chatts.	38	8.35	0.220	552	159.38	0.289	38	8.35	0.220
50	Chatts.	60	13.57	0.226	732	225.57	0.308	60	13.57	0.226
51	Chatts.	50	11.42	0.228	437	111.86	0.256	634	177.25	0.279
52	Chatts.	60	11.92	0.199	634	207.60	0.327	448	120.26	0.268
57	Chatts.	51	14.78	0.290	62	27.60	0.450	196	73.81	0.376
58	Chatts.	44	11.71	0.266	176	82.17	0.467	375	130.20	0.348
59	Chatts.	51	10.64	0 208	640	208.62	0.326	462	112.60	0.244
60	Chatts.	65	12 67	0.195	587	143.26	0.244	1 266	317.41	0.250
62	Chatts.	59	15.73	0.266	1 049	381.18	0.382	627	206.31	0.328
63	Chatts.	88	19.00	0.216	678	296.65	0.438	552	151.59	0.275
64	Chatts.	36	8.14	0.226	868	309.56	0.357	500	136.69	0.273
65 1/2	Chatts.	33	7.74	0.234	791	312.36	0.394	312	63.38	0.203
	Totals. . .	1 112	$268.06	0.241	13 155	$4 579.47	0.348	7 891	$2 217.62	0.281

Per cent in reduction in cost since test : 19.3.

Testing the proposed method.

In order to put the conclusions to a practical test, ties were inserted as shown under case 4 by the same section gang reported under case 1. Conditions were practically the same and the location was only a few telegraph pole panels removed from the first test. The methods followed were based on conclusions arrived at as above and corresponded closely to those used in case 2.

TABLE 3.

Comparative cost of tie insertions in chatts or gravel ballast on the Eastern Division. 1924.

		Division.	Terminals.	Outside.	System.
1 January to 30 June . .	Ties.	32 840	2 034	30 806	
	Cost.	$11 650.86	$844.77	$10 805.09	
	Average cost . . .	0.356	0.415	0.351	0.349
July	Ties.	12 747	166	12 581	
	Cost.	$4 094.54	$ 78.76	$4 015.78	
	Average cost . . .	0 321	0.473	0.319	0.332
August.	Ties.	15 443	1 263	14 180	
	Cost.	$4 894.89	$490.56	$4 404.33	
	Average cost . . .	0.317	0.388	0.310	0.333
September.	Ties.	11 315	1 245	10 070	
	Cost.	$3 377.70	$199.95	$2 877.75	
	Average cost . . .	0.298	0.402	0.288	
October	Ties.	6 950	728	6 222	
	Cost.	$1 9-3.88	$253.92	$1 729.96	
	Average cost . . .	0.285	0.349	0.278	0.318
November	Ties.	11 566	264	11 302	
	Cost.	$3 034.15	$73.98	$2 960.17	
	Average cost . . .	0.262	0.280	0.262	0.325
December	Ties.	3 898	98	3 800	
	Cost.	$1 077.52	$36.21	$1 041.31	
	Average cost . . .	0.277	0.369	0.274	0.328

The result showed a slight variation in time from case 2 with respect to the different operations. However, the variations were not greater than might be attributed directly to the distribution of the assistance by the foreman and the net result was almost the same, for there was only one-tenth of one minute difference in the total time used per tie. Other tests were made with gratifying results.

From the above it is clear that the method of tie installation has a very direct bearing on the cost. It is, of course, self-evident that much will depend on the ingenuity and industry of the foreman and the willingness, skill and industry of the men. We have had the best co-operation from the men and the foremen, except in a few isolated cases. We have handled the entire study with the idea of getting co-operation rather than of trying to force anybody to conform to our plan, the idea being that intelligent supervision is based on the education of the men rather than on the driving of them.

The standard method.

The method we have finally adopted and have put into effect in many places, but not universally, is a follows:

1.—The indicating of the ties to be replaced is done during the annual inspection, subject to the exercice of the foreman's judgment when the actual renewals are made. A record is kept of the exact number of ties required on each mile. This record is made at the time of the annual tie inspection.

2.—The unloading and distribution of ties can be handled effectually by unloading from trains if the road master and section foreman have the record with them. The section foreman, of course, has an accurate idea of just what ties should be unloaded on each mile. His judgment in connection with the road-master's supervision by means of written record gives us a very good distribution from cars. The only trouble experienced with this method arises from ties rolling down the bank, resulting in considerable expense in bringing them back. In keeping the cost of installing ties, we assume that the ties are properly distributed ahead of time. It is impossible to get away from a small amount of rehandling of ties on push cars or dragging them along the rail but we try to keep this down to a minimum.

3.—In pulling spikes, one man should pull the spikes ahead of the gang. It is usually best not to pull very many at one time, as where renewals come side by side enough spikes must be left in to keep the track safe.

4.—The remainder of the work should be divided into two sets of operations. The first includes digging out, pulling out the old tie, pulling in the new tie and tamping. Two men, never more, should be placed at each tie. If there is an odd man he may pull spikes, dig out and help nip, his exact duties depending upon the size of the gang. He should be one of the best men in the gang. For small gangs, the foreman should do all of the nipping. This puts him in a position where he can supervise the work and still be helping at the actual labor. If the foreman is not on hand to nip, one of the men should nip and another tamp the ends enough to hold the tie, after which both finish tamping. Each pair of men should work not closer than half a rail length apart. Working too close together not only causes loss of time, but it is dangerous. On the other hand, working reasonably close together improves the morale of the gang, creates a friendly spirit of competition and makes closer supervision possible.

The second set of operations includes plating, spiking and dressing up ballast. For small gangs, it is best to leave the second set of operations until near the close of the day's work, unless the ties are so widely scattered that this is impracticable. This allows the new ties to settle under traffic before spiking and dressing. Spiking on a solid bed is easier for the men and dressing ballast after the tie has settled eliminates the depression otherwise formed by the tie settling.

5. — *Digging out the old tie.* Dig out at the side of the tie and through the shoulder on the side on which old tie is to be pulled out. If the old ties are to be burned, it is usually best to pull them out on the side away from the telegraph wires. The trench should be dug out about one inch deeper than the bottom of the old tie, or just as little as experience teaches is necessary to remove the old tie. It will be found that the trench must be dug a little deeper for rock or coarse gravel ballast. Drive the old tie over into the trench. Remove the tie plates. Pull the tie out. If two or more ties are coming out side by side, remove in pairs.

6. — *Pulling in the new ties.* Clean out the trench for the new tie, handling the ballast just as little as possible. Notice whether the new tie is large or small and clean out accordingly. Be sure to dig out the shoulder low enough so that the front

end of the tie does not plow as it is pulled in. Adze the tie if necessary to fit the rail.

7. — *Tamping.* Tamp the tie snugly against the rails, nipping the tie while tamping. Do not spring the rail unless there are no plates. Plates should be placed conveniently at hand on the ends of the ties. If it is necessary to spike a tie to keep the track safe, put on plates, spike and tamp to the rail without springing. If no plates are to be used, the rail should be sprung with the nipping bar while the tie is being tamped. Use a nip plate for a heel. Where no plates are used, the foreman should do the nipping. Extreme care should be taken not to raise or spring the rail too much—just enough to allow settling to the old level.

This completes the first set of operations. The men continue digging out, pulling in, and tamping, until the foreman believes it will take the rest of the day to complete the spiking and dressing.

8. — *Distributing spikes.* One man should go ahead of the spikers and distribute the spikes.

9. — *Plating.* The foreman and one man take a jack, bar and shovels. The foreman places the plates under the rail while the man springs the rail with the jack just enough to let the plate under. This raises the track the thickness of the plate and allows for settlement to the original level. At joints or an occasional missing plate, spring the rail about the thickness of the plate and retamp any new ties that were plated and spiked for safety.

10. — *Spiking.* Two men follow the spike distributor and platers and spike one side, then spike the other side to gage. Unless the ties were inserted very close together it saves time to have the men spike both sides as they go.

11. — *Lining.* If many ties were taken out to the rail length, it may be that the track will be left slightly out of line. If so, it should be lined and the time used charged to inserting ties. Lining is seldom necessary.

12. — *Dressing up.* The men distributing spikes and placing plates will have finished long before the spikers and will then fall back and dress up. Centers should be dressed up first, then the shoulders. If the spikers get through spiking before the ballast dressers catch up, they help dressing up.

It is important that the old roadbed be disturbed as little as possible. At places where ties are renewed almost out of face, it is best to put in only a part of the new ties at one time. Enough ties should be left in the track to hold the track to line. This is especially important where there is danger of the track « bucking » out of line due to expansion. Also it is cheaper to put in the ties this way.

Ties are put in the cheapest where two ties come out side by side, so that only one trench is necessary. When more than two ties come out, it becomes necessary to handle the ballast more. Also it may become necessary to plate and spike some or the ties to make the track safe, necessitating a change of tools, and later retamping when plates are placed on adjacent ties.

Many little points continually arise in connection with the handling of work of this kind which are important in the aggregate. It is especially important that the foreman, while taking an active part in the labor of putting in ties, be in position to supervise every detail of the work done by his men, otherwise a good and efficient job will not be obtained.

Everyone realizes that putting in ties, especially in hot weather, is hard work. It is, therefore, necessary that the men be given every possible opportunity under the circumstances to keep cool and, therefore, good, fresh water of proper temperature should be provided. The water

keg should be kept in as cool and convenient a place as is possible. Such little helps as throwing a saturated blanket or gunny sack over it, all enter into the cost of doing this kind of work. Many such expedients occur to the foremen and are used to much advantage by them. The necessity of using care and good common sense in handling men is, of course, self-evident in a general way, but everything done to educate the foremen to do things necessary along this line is important.

[621 .335 (.71)]

Canadian National Diesel-electric cars.

Figs. 1 to 3, pp. 124 to 127.

(*Railway Mechanical Engineer.*)

A new development in motor rail car design has been introduced by the Canadian National in the construction of nine Diesel-electric cars that are now being built at its Point St. Charles shops, Montreal, Que. Seven of the nine units are single cars (fig. 2) having an overall length of 60 feet and the remaining two (fig. 1) are of the articulated type with an overall length of 102 feet. Including the articulated construction of two of the cars, the principal features in the design are the four-cycle Diesel engines and the use of three-passenger seats to obtain maximum seating capacity.

The engines.

The engines installed in these cars were manufactured by William Beardmore & Co., Ltd, London, England. The design is a modification of this company's standard aeroplane engine which was changed to meet the service conditions of rail car operation. These engines conform to a modified Diesel cycle of the solid injection four-stroke cycle type and are arranged with four cylinders in line for the small unit which is used on the 60-foot car, and eight in line for the large unit which is used on the articulated car. The cylinders in both engines have 8 1/4 inch bore by 12 inch stroke and develop 185 B-HP at 700 revolutions per minute in the small unit and 340 B-HP at 650 revolutions per minute in the large unit. The engine in the 60-foot car weighs 2 750 lb. and that in the articulated car weighs 5 450 lb., or a fraction under 15 lb. per horsepower for the smaller engine and slightly more than 16 lb. per horsepower for the larger engine.

The low weight per horsepower was obtained through the selection of materials. The designers were able to reduce the thickness of the materials to a minimum through the use of high tensile steels and special alloys. For example, the crank case is of cast steel; the cylinder liners are made of forged steel; the cylinder heads, of cast aluminum; the valve seats, of alloy steel; the pistons, of forged aluminum; the crank shaft of special forged alloy steel; the sump cover, of sheet steel; and the connecting rods, of special forged steel.

A feature in the design of these engines is the steel monobloc crank case, the upper part of which is bored out to receive steel liners, and thus form the water jacket around the liners. The

main crank case casting carries the crank shaft bearings and also the base supports for bolting the engine to the underframe of the car. Large inspection doors are provided which give access to both end bearings. The lower part of the crank case consists of a light tray with an oil sump which is secured to the underside of the main casting. The main bearings are equipped with phosphor-bronze bearings lined with babbitt metal and are lubricated by a continuous oil pressure system. The connecting rods are made from special steel forgings, the top end bearing of which has a solid phosphor-bronze bushing, while the end is fitted with a pair of phosphor-bronze bushings lined with babbitt metal and fitted with an adjustable liner. Both bearings of the connecting rod are arranged for pressure lubrication.

The pistons are made from forgings of a special aluminum alloy and are machined all over and balanced before finishing. Each piston carries four cast iron piston rings in addition to a scraper ring. The steel liners which are pressed into the main crank casing are also of light construction. The cylinder heads are made of an aluminum alloy and are provided with large spaces for the circulation of cooling water. Each cylinder head carries two exhausts, two valves and a central automatic spray valve as well as a compression release valve. The exhaust from each cylinder enters a manifold on the side of the engine for which one exhaust pipe for every four cylinders is carried vertically up through the roof.

The main crank case is a light steel casting and carries the housings for the ball bearings on which the gear wheel spindles run. Attached to the main gear case are the duplex lubricating oil filters, the oil pump and the centrifugal type cooling water pump, which is also equipped with filters.

Separate fuel pumps which deliver the fuel to the atomizers at from 8 000 lb. to 10 000 lb. per square inch, are employed for each cylinder. A primary pump maintains an oil pressure on the suction side of the main fuel pumps. The injection is timed and the engine output is controlled by varying the effective piston delivery stroke. Any excess oil is delivered back to the fuel tank through a by-pass gear. A light residue oil of 0.86 specific gravity is used for fuel.

Engine auxiliaries.

A centrifugal type governor driven off the crank shaft is coupled to the fuel pump control and is so arranged as to increase or decrease the oil supply to the fuel distributing system. It is fitted with an emergency device to cut the fuel pumps out of action should the revolutions per minute of the engine for any reason be increased above the desired speed.

A centrifugal pump is used to circulate cooling water through the engine. This pump is mounted on the main gear case and can be easily detached for examination. Flow indicators are installed in the lubricating oil and cooling water circuits which indicate a stoppage of flow by lighting a lamp in the operator's room.

The tanks for water, fuel oil and lubricating oil are all made of 3/16-inch and 1/4-inch aluminum plate and are located in the engine room. The piping is of aluminum, except in a few places where copper is used. The water tank on the 60-foot car has a capacity of 120 gallons; the fuel oil tank, 75 gallons, and the lubricating oil tank, 50 gallons. On the articulated car the water tank has a capacity of 240 gallons; the fuel oil tank, 150 gallons, and the lubricating oil tank, 100 gallons.

Midwest air filters are applied to all of the cars for filtering the air supply

to the engines. The filters used on the 60-foot car are mounted on the ceiling of the engine room, while those on the articulated car are mounted on the left-hand wall of the engine room which is provided with shutter inlet to keep out the rain or snow.

The 60-feet car has two full-size Rome Turney radiators mounted on the roof for cooling water and one half-size for cooling lubricating oil. The articulated car has four full-size radiators for cooling water and one full-size radiator for cooling lubricating oil.

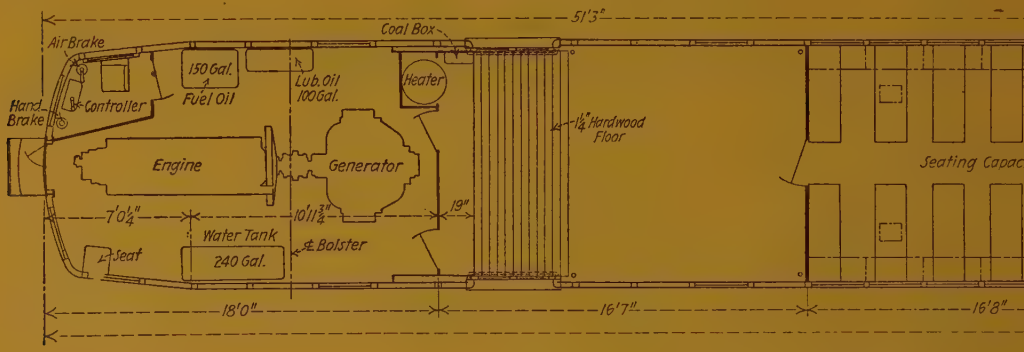


Fig. 1. — Floor plan of the articulated

The lubricating oil is forced under pressure to all working parts, including those of the cam shaft. Oil is drawn from the well in the sump, located at the gear case end of the engine, and is then forced through double filters via the cooler on the roof to the main supply tank. These filters can be cut out and cleaned while the engine is running. The oil then flows by gravity from the tank through a second pair of filters to the compressor pump which forces it through the crank shaft to the journals and pins and thence to the small ends at about 60 lb. pressure. A connection also leads to the cam shaft and oil is forced up through the center of the cam shaft to the bearings. Provision has been made to drain the unused oil in the engine back to the sump well.

The electrical equipment.

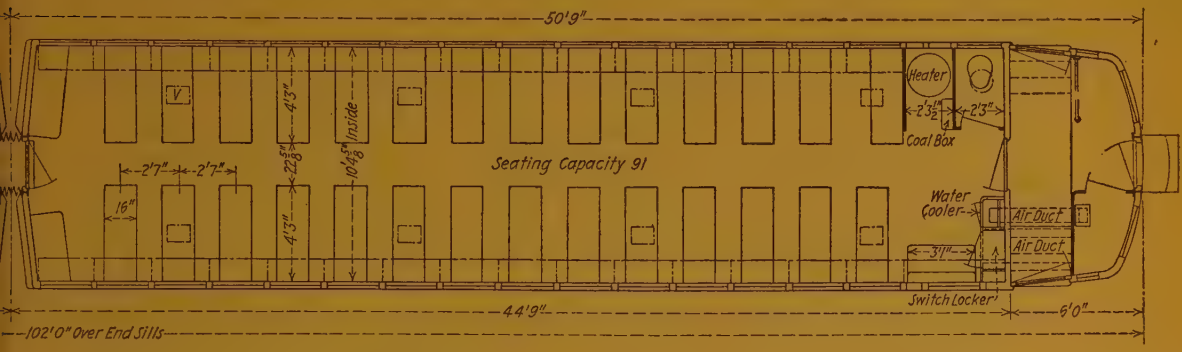
The electrical equipment on the articulated car was manufactured by the Westinghouse Electric & Manufacturing Company, Pittsburgh, Pa., and consists of a 200-kw., 600-volt d. c. generator mounted on a common bed plate with the engine and connected to it by a Fast flexible coupling. Pressed felt liners 1 1/2 inches thick are placed between the bed plate and the car sills to absorb vibration.

The generator is differentially compound wound, the shunt field being excited from a 300-volt battery. The motors are 600-volt railway type 548-C-8, with a one-hour rating of 145 amp. connected permanently in parallel and mounted two on each of the front and rear trucks and connected to the axles by helical gearing.

The car is operated by master controllers located at each end, different speeds being obtained by a resistance control of the main generator field. Besides the master controllers, the main control apparatus consists of a switch group comprising eight electro-pneumatic switches, two reversers, an overload trip relay, and a sequence drum. The auxiliary control apparatus consists of

a potential relay, an ampere hour meter, a battery charging relay, a field relay, a throttle valve, a control and reset switch and the necessary knife blade switches for the control of the several circuits. False operation of the various circuits is prevented by necessary interlocking between controls, which also makes the operation practically automatic.

The air for the magnet valves is taken from the air brake system and is maintained at about 70 lb. pressure, the electro-pneumatic control being the



rs recently placed in service by the Canadian National.

standard H. L. equipment throughout. The acceleration of the car is practically automatic as the control can be thrown to the « full » position, allowing the sequence drum to increase the generator voltage in four or five seconds. All controller positions are, of course, running positions, and lower speeds than the maximum can be obtained by intermediate points on the controller.

The engine is started by the generator driven as a motor, from the 300-volt battery, this starting position being obtained from the controller by moving the operating handle contrary to its operating direction. The engine starting position is also the battery charging position when the car is standing. By motoring the generator the 300-volt battery brings the engine to a speed of about 200 revolutions per minute at which speed it fires on the first compression, the starting current for about two seconds being a maximum of 480 amp. down to 230 amp. at 150 volts. The battery voltage is applied to the generator through resistance steps and at the same time the engine throttle is moved by an electrically controlled air cylinder to full fuel position.

The battery is composed of 150 cells, M. V. A. 17 Exide Ironclad, and is located in two sections in steel boxes suspended from the floor of the rear half of the car. With the car running and the controller on either of the last two notches, the potential relay cuts in and allows the generator current to charge the battery. This continues as long as the controller is on either of the last two notches or until the charging current is cut off by the ampere-hour meter.

Besides being used for starting purposes, the battery also supplies the control circuits at 30 volts; the generator field excitation at 300 volts; the two air compressors at 300 volts, and the car lighting at 30 volts. Low voltage circuits can be distributed over 90 of the 150 cells and standard lamp regulators are used to compensate for the charging

voltage. Emergency switching is provided so that any of the 30-volt sections can be charged from the generator while the car is standing. One of the main reasons for having the 300-volt battery is that in case of necessity, owing to a total engine failure, the car can be moved on half voltage to the next siding, in order to clear the main line.

In carrying the circuits across the articulation, every effort has been made to secure accessibility and reliability. All the control wires are carried through the ceilings of the cars, terminating at each side of the articulation in junction boxes located in the car ceiling. The only heavy cables crossing the articulation are the generator bus liners to the motors, the battery line to the generator and the train line lighting circuit. By locating a reverser on each half of the car, the necessity of carrying the motor leads across the articulation is avoided. Multiple unit control has been installed so that two or more cars can be operated from any one operator's position.

The electrical equipment of the 60-foot car was manufactured by the British Thomson-Houston Company, Rugby, England and the General Electric Company, Schenectady, N. Y. The generator, which was shipped with the engine from England, is a 105-kw., 600-volt d. c. differentially compound wound machine mounted on a common bed plate with and rigidly connected to the engine. Pressed felt liners 1 1/2-inches thick are placed between the car sills to absorb vibration. On the same shaft with the generator is mounted a 6-kw. 60-volt exciter. The balance of the electrical equipment consists of two G. E. 240-A, 600-volt, 150-amp. (one hour rating) railway motors, mounted on the front truck and connected through helical gears. The controllers located at each end connect the motors in series, parallel or shunt field forward, and series or parallel reverse.

A 120-volt M. V. A. 17 Ironclad Exide battery is carried underneath the rear of the car. Thirty cells are suspended from the floor in a steel battery box on each side of the car. This battery furnishes starting current for driving the generator as a motor in a manner similar to that described for the articulated car, only 16 cells of which, however, supply the excitation of the exciter field and the car lighting. The 120-volt battery is charged from the generator by a special charging circuit used while the car is standing. The 32-volt portion is automatically charged by the exciter when its voltage is higher than the battery voltage.

The car speed is controlled by the engine throttle, which is mechanically connected to an operating lever located in the operator's cab at each end of the car. The electrical controllers merely connect the motors to the generator circuit in series or parallel and are not used to operate the car. The first movement of the throttle lever closes the throttle relay switch, thus closing the exciter field circuit, and allowing the generator voltage to build up from zero across the driving motors. A further opening of the engine throttle increases the generator voltage and, therefore, the car speed.

Interior of cars.

The two types of cars contain many similar features of design and construction. The bodies of both the 60-foot and the articulated cars are of steel construction throughout. The interiors are finished in mahogany and have a 5/16-inch Agasote ceiling painted in cream color. Double floors are applied throughout with the exception of the engine rooms where a single floor 1 1/4 inches thick, covered with checkered aluminum floor plates, is used. The floor consists of one layer of 13/16-inch white pine and a top floor of 5/8-inch

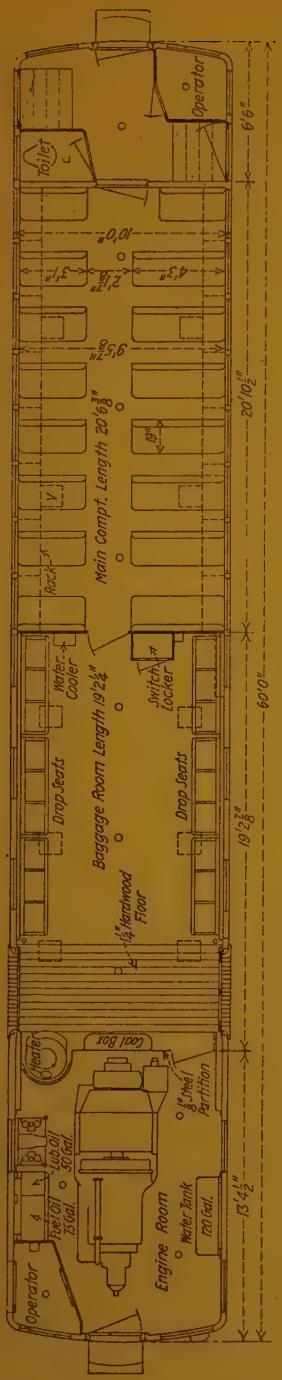


Fig. 2. — Floor plan of the 60-foot motor rail car.

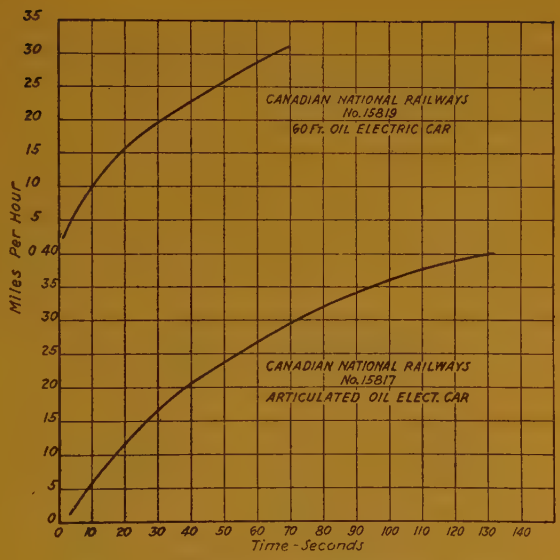


Fig. 3. — Chart showing acceleration curves for the 60-foot and articulated cars on level track.

fir, with a double thickness of building paper between. The side lining below the windows is 5/16-inch Agasote painted to match the interior finish. Both types of cars are equipped with single windows of cherry, to which storm sash can be applied for winter use. Three-ply Salamander insulation is applied below the windows, two-ply above the windows and one-ply on the ceiling. The roof boards are 1/2-inch whitewood covered with No. 6 canvas laid in white lead. Parcel racks running the full length of the passenger compartments are provided.

Electric lighting is provided from 30-volt storage batteries. Aluminum conduits for carrying the lighting circuits, power and control circuits are used throughout. Ventilation is provided by exhaust type ventilators in the roof. Smith hot water heaters are used for heating both types of cars. The 60-foot car is equipped with one hot water heater which is placed in the

baggage room. The articulated car has a heater located in the baggage room and one at the rear end of the passenger compartment. All of the pipes used in the heating system are of aluminum.

Each unit of the articulated cars consists of two bodies mounted on three four-wheel trucks. As shown in the floor plan of the articulated car, the front half contains the engine room, baggage room and smoking compartment which has a seating capacity of 35 persons. The rear half has a seating capacity of 91. The seats used in both compartments are of the Heywood-Wakefield reversible type, placed 2 ft. 7 in. center to center, and are upholstered in Spanish leather. Forty of the seats each accommodate three people while three seats provide for two passengers each, giving a total seating capacity for the articulated car of 126. The inside width is 10 ft. 4 5/8 in. which permits the installation of seats 4 ft. 3 in. wide and allows an aisle space of 1 ft. 10 5/8 in.

The length over the end sills of the front half of the articulated car is 51 ft. 3 in., and the length over the end sills of the rear half is 50 ft. 9 in. The overall height is 14 ft. 4 3/8 in., and the width over the side sills is 10 ft. 10 3/4 in. The inside length of the engine room of the articulated car is 17 ft. 6 in., and the inside length of the baggage compartment is 16 ft. 6 in. The partitions between the engine room and baggage room are of steel and are so constructed that they can be removed if necessary to work at the power unit. Roof hatches are provided directly over the engine and generator so that either may be removed by a crane for repair purposes. The hatch covers are provided with four ventilators operated from the engine room.

The three trucks of the articulated car are of Commonwealth design having 5-inch by 9-inch journals and 36-inch rolled steel wheels. The journals are equipped with S. K. F. self-alining roller bearings. Motors are mounted on the front and rear trucks only.

The center truck of the articulated car carries one end of both the front and rear body sections. Each section is provided with a special cast steel end sill to which are bolted center castings, one of which sets within the other, both engaging the truck center plate. A safety type locking pin is used, and safety bars are also provided. A one-piece canvas diaphragm encloses the space between the front and rear halves and a diamond steel foot plate is located at about the floor level.

The brake equipment is Westinghouse, schedule A. M. F. The air pressure on the articulated car is supplied by two DH-16 compressors connected in parallel. The braking ratios are based on 50-lb. cylinder pressure, being 83 % on the front and rear trucks and 75 % on the center truck. The trucks are equipped with the A. S. F. suburban type Simplex clasp brakes. The front and center trucks are fitted with a new design of brake which consists of a standard Type D freight brake cylinder mounted on each side of the truck frame and connected directly to the front brake gear. A flexible cylinder pipe connection is located near the center of the truck. On account of insufficient clearance, the cylinder for the rear truck is attached to the car body.

The seats in the 60-foot car are of the same design and manufacture as those of the articulated car. They accommodate three persons on one side and two on the other. In addition, the baggage room of this car is provided with drop seats of wooden construction giving a total seating capacity of 57.

The width over the side sills is 10 feet which allows an inside width of 9 ft. 5 7/8 in. The overall height is 15 ft. 3/4 in. The distance between truck

centers is 39 ft. 3 in. making a total wheel base length of 46 ft. 1 in.

Compressed air for the 60-foot car is supplied by a General Electric CP28-D compressor. The braking ratio is 83 % based on 50-lb. cylinder pressure. The trucks are equipped with single shoe type brake with the standard body brake arrangements. They have 36-inch rolled steel wheels, A. R. A. boxes and brasses, cast steel side frames and built-up bolsters. The front truck carries two motors and has 5-inch by 9-inch journals. No motors are used on the rear truck which is equipped with 4 1/4 inch by 8-inch journals.

Principal dimensions and proportions of the Canadian National Diesel-electric cars.

	60 foot cars.	*Articulated cars.*
Total weight	101 000 lb.	188 000 lb.
Total wheel base	46 ft. 1 in.	85 ft. 10 in.
Diesel engine :		
Type	4 cylinders, 4 cycle.	8 cylinders, 4 cycle.
Rated capacity	185 B.HP. at 700 r.p.m.	340 B.HP. at 650 r.p.m.
Cylinders, diameter and stroke	8 1/4 inches by 12 inches.	8 1/4 inches by 12 inches.
Weight	2 750 lb.	5 450 lb.
Generator :		
Type	Thomson-Houston, 105 kw. d.c.	Westinghouse, 200 kw. d.c.
Voltage	600	600
Motors :		
Number	2	4
Type	General Electric type 240-A.	Westinghouse, 200 H. P.
Capacity of fuel tanks	75 gallons.	150 gallons.
Length over couplers	60 feet.	102 feet.
Width, inside	9 ft. 5 7/8 in.	10 ft. 4 5/8 in.
Height, overall	15 ft. 3/4 in	15 ft. 4 3/8 in.
Diameter of wheels	36 inches.	36 inches.
Total seating capacity	57	126

Miniere window cleaners are installed on the front window of each operator's room. Each car is equipped with a listening tube which runs from the engine room to the rear operating room. Sand boxes are suspended from the underframe and are filled through holes in the car floor. Hanlon sanders provide sand to the front of the front truck and to the rear of the rear truck.

It is reported that both cars have attained a speed on level track of approximately 60 miles per hour and show a low fuel consumption. Both cars have sufficient power to handle a trailer over an average profile at a proportionally reduced speed. Car accelerations up to 40 and 30 miles per hour respectively have been made in actual test (fig. 3).

[621 .132.5 (.73)]

A new two-cylinder cross compound locomotive with water-tube boiler working at 350 lb. per square inch

(The « Horatio Allen »).

Figs. 1 to 4, pp. 131 to 134.

(From *The Engineer*.)

The engine bearing this historic name has been built by the American Locomotive Company to the requirement of Mr. J. E. Muhlfeld, consulting engineer to the Delaware & Hudson Railroad, whose advanced ideas on what should constitute the modern steam locomotive are widely known.

This locomotive differs greatly in appearance from the ordinary and, in formulating this design, features which are in themselves not new in principle have been adopted, which, taken in combination, have produced a locomotive of more than ordinary interest.

Without doubt, the leading feature is the boiler. Recognition of the advantages offered by high-pressure steam and the desire to put them to practical use, dictated a boiler of the water-tube description, especially as it was desired to get away from the fire-box of normal type, with its large flat direct stayed surfaces, which were deemed unsuitable for a pressure of 350 lb. per square inch.

The fire-box is composed of two headers made up of parallel stayed plates flanged and riveted around the top and sides, and secured to steel foundation castings at the bottom. Circular openings through these headers at the upper and lower corners receive water drums, those at the top being 30 inch diameter inside and those at the bottom 20 inch. These drums pass completely through the headers, and have port ways cut in them where they go through the header steam and water spaces. The top drums extend forward along the barrel section, and are secured by a built-up steel saddle, as shown in figure 3, connections being made by further ports cut through the tubes. Flanged ends are riveted into all the drums, as shown, and mud doors are fitted in the usual manner. The barrel section of the boiler contains the flues and tubes, forty-two of the latter and 145 of the former, their sizes being 5 3/8 inches and 2 inches. This part of the boiler is completely filled with water and the steam space is in the top drums, where the water level is about 3 inches below their centre. The barrel is in two courses, and is riveted to the front sheet of the forward fire-box header, where it is flanged outwards to take the rear barrel section, whilst the inner sheet of the header is flanged inwards to receive the tube plate (see fig. 3).

Tubes to the number of 306 form the side heating surfaces of the fire-box; 102 are 2 1/2 inch and 204 2 inch diameter. These tubes are expanded into the drums. It will be seen that the stayed surfaces have been much reduced, and those remaining are flat and parallel except just round the fire-door. Eight tubes of 3 1/2 inch diameter run longi-

tudinally between the upper drums over the fire-box, and join the front and back headers. A secondary superheater is placed just above these tubes in two others of equal diameter, and the space between the upper drums and above these tubes is covered in by a fireproof insulated roof covering. There are also six 3 1/2 inch arch tubes, which support a brick arch running continuously from the tube sheet to the back header (see fig. 1). In this manner the fire-

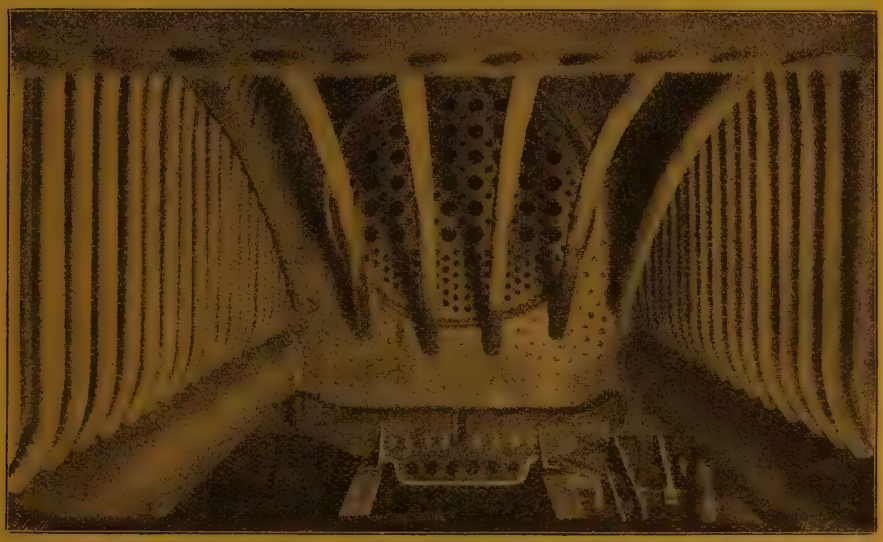


Fig. 1. — Interior of fire-box of the « *Horatio Allen* ».

box is completely divided into two sections. The object of this is to direct the flame and hot gases outwards on each side, and through the staggered side tubes, and thence into the upper combustion chamber, and then, finally, through the tubes and flues to the front end.

The barrel is 66 3/8 inches diameter inside at the rear end, and is built up of plates 1 1/16 inch thick; the front tube plate is 5/8 inch, and the rear 1/2 inch thick, and the tube length is 15 feet. The back header is formed of plates 5/8 inch and 7/16 inch, the thicker being the outer plate, whilst the front header has a 1/2 inch inner and a 7/8 inch outer plate. Outside at the bottom the fire-box measures 156 inches long by 128 1/2 inches wide.

The superheater consists of 42 units, each of which is formed by a single loop. The unit pipe leading from the saturated side of the header is twisted round the return length in a spiral, the two pipes being threaded and welded into a cast steel return bend, which is placed 12 inches from the fire-box tube sheet. The whirling action imparted to the wet steam passing through the twisted portion of the elements is held to bring such moisture as the steam may contain into intimate contact with the heating surfaces, thus producing an effective heat transfer. Steam from the drifting valve passes through the elements when the engine is coasting, and they are thus protected from overheating.

The superheater header is fixed over the opening in the smoke-box, shown in

Fig. 2. — General view of the locomotive « *Horatio Allen* ».

figure 4. The superheating surface is 579 square feet, which is equal to 15.3 % of the total combined heating surface. This comparatively small superheater was adopted because of the desire to keep the total temperature to 600°. Fah., and as the saturated steam temperature at 350 lb. pressure is already 436° approximately, only 164° have to be added by the superheater against 262° at the more usual pressure of 200 lb. for 650° total temperature. Until it has been determined what the effect of the high pressure and high temperatures will be, it has been considered prudent not to exceed the temperature stated.

The total gas area through the tubes and flues is 1 008 square inches, 666 square inches of which are in the flues and 342 in the tubes; 66 %, therefore, of the gas area is available for superheating.

The ratio between the gas area through the tubes and flues and the area of the fire grate is 1 to 10.2.

Steam is taken from the forward sections of the steam drums, a collector pipe, 6 inch diameter, being fixed near the top of each for this purpose. The top surface of each pipe is perforated with several rows of 1/2 inch holes to distribute the gathering surface, and thus prevent any tendency for a local surge to lift the water. From these pipes the steam passes out of the drums to a yoke header casting fixed between the two drums, on the front flange of which is bolted a centrifugal drier or de-saturator. Tests have shown that the effect of the internal pipe arrangement and the drier has been to limit the moisture content to from 2 to 3 %.

The throttle valve is of an entirely new design. It consists of two separate valves of the Chambers type. The first and smaller valve is used at starting; it takes steam at 300 lb. through a reducing valve. When the engine has been started through this valve the main valve may be opened, and continued opening of this valve causes the lever controlling the auxiliary valve to be picked up and moved with the lever working the main valve. Closing the main valve automatically unlocks the connection between the two levers, and thus the preliminary valve lever is free to be moved independently at starting. The « simpling » of the cylinders at starting is controlled by a Melling intercepting valve. Change to compound action may be automatic or manual, at the will of the engineman. The receiver pipe from the high-pressure to the low-pressure steam chest passes over the smoke-box to the low-pressure cylinder on the left side of the locomotive.

Figure 2 shows the run of the main steam and receiver connections, and being a view of the right side of the engine shows the high-pressure cylinder.

With the provision of a working steam pressure of 350 lb. it is not surprising that counpound expansion has been adopted, but to find the old two-cylinder cross-compound arrangement again revived is interesting. It is many years now since the days of the two-cylinder compound, and several other systems have in the meantime been tried in greater or less numbers, and while those conversant with locomotive construction in the United States realise that the four-cylinder engine is hardly practicable for very high powers, they will undoubtedly consider that a three-cylinder compound might offer certain well-defined advantages over the two-cylinder arrangement. Be that as it may, Mr. Muhlfeld has fitted his engine with two cylinders which are respectively 23 1/2 inch and 41 inch diameter, with a 30 inch stroke. thus having a ratio of 1 to 3 approximately. The ratio of the receiver volume to that of the high-pressure cylinder is 2 1/2 to 1.

Piston type valves are used. They are 12 inch and 14 inch diameter, and are operated by the Young system of valve motion, the reversal of which is

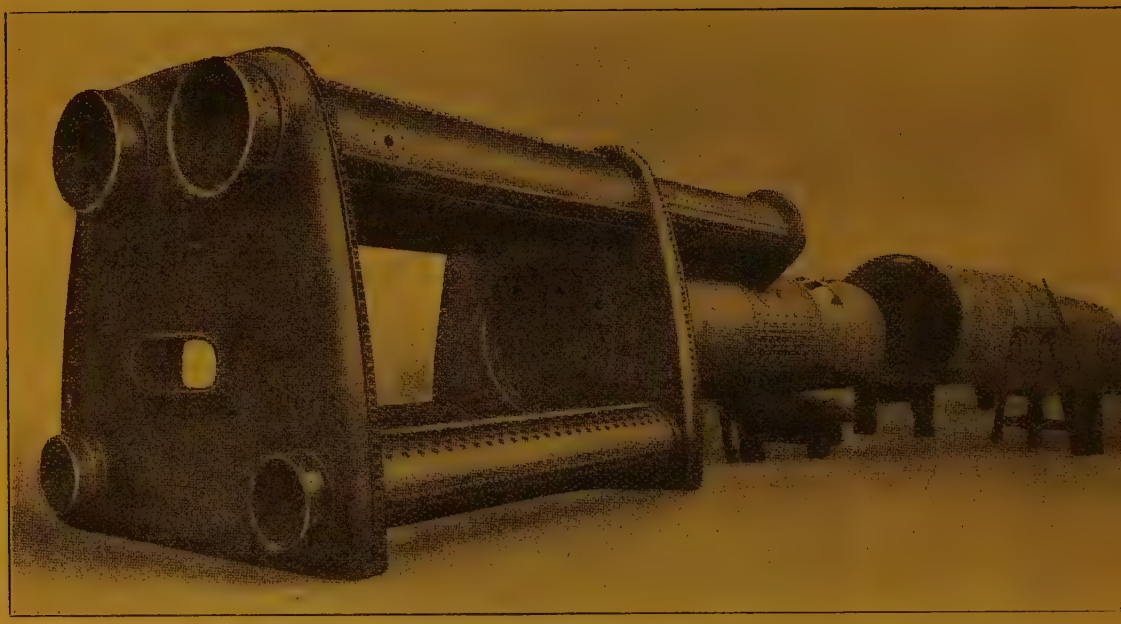


Fig. 3. — The boiler under construction.

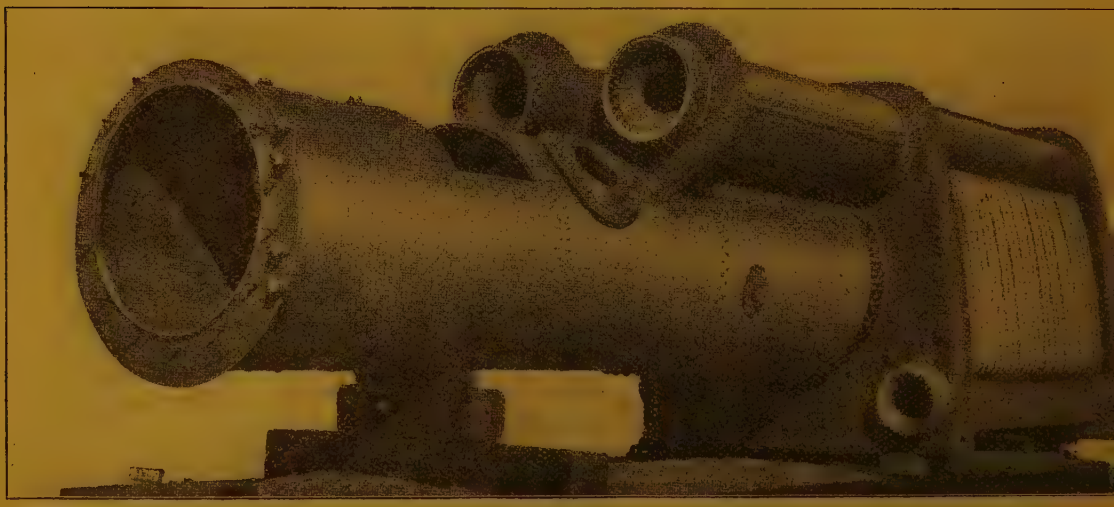


Fig. 4. — The boiler completed and ready for its fittings.

done by a power gear. The high-pressure valve is single-ported and the low-pressure double-ported. The steam lap is 1 3/8; the lead, 1/4; and the maximum travel, 9 inches.

The estimated tractive power in compound gear is 70 300 lb., and when working simple expansion .84 300, the adhesive factors (adhesive weight ÷ tractive effort) under these conditions being 4.25 and 3.54 respectively. In actual service the locomotive has developed the following pulls on the drawbar:

	Lb.
Starting simple, with booster	105 000
At 4 miles per hour, simple	95 000
At 5 miles per hour, compound.	75 000
At 8 miles per hour, compound.	67 000
At 10 miles per hour, compound	65 000

The calculated mean effective pressures in compound gear are as follows:

Speed, miles per hour.	H. P. cut off, per cent.	M. E. P., lb.	L. P. cut off, per cent.	Receiver pressure.	M. E. P., lb.
5	89	249	89	90	80
10	75	224	79	85	73
20	50	178	56	80	57
40	25	97	35	70	34

The cylinder horse-power is computed at 3 000, whilst that of the boiler is about 3 565, so that the locomotive has a 119 % boiler.

In designing, the estimators calculated a total engine weight in working order of 312 000 lb., and that of this 268 500 lb. would be carried by the coupled axles, and 43 500 lb. on the leading truck. Actually, the weights are 298 500 lb. available for adhesion, and 49 500 lb. on the truck, making a total of 348 000 lb. — say, 156 long tons — equal to an excess over estimate of 11.54 %. These increases are due mainly to the radical design of the boiler and other parts, and to the high factors of safety used, particularly in reference to the boiler, engines and framing.

It is considered that subsequent similar locomotives may be considerably lighter. With the actual weights as they are this engine is light compared with the total boiler and superheater surfaces, for it weighs only 53.3 lb. per square foot of total heating surface, and, taking the cylinder horse-power at 3 000, the weight works out to 116 lb. per indicated horse-power. Actually this locomotive working compound at 18 miles per hour can pull 47 000 lb. on the tender drawbar, equal to a drawbar horse-power of 2 260, and at this rate the weight per unit of power delivered is 154 lb. Furthermore, assuming an overall mechanical efficiency of 75 %, we get a cylinder power equal to 2 825 indicated horse-power, or 126.1 lb. per indicated horse-power.

Further particulars of this locomotive are as follows :— The driving wheels are 57 inch diameter, and those of the leading truck are 36 inch, and the main journals are 12 inches by 14 inches, and the others 11 inches by 14 inches.

The additional two-element superheater already mentioned as being fitted in tubes running above the fire-box, furnishes superheated steam for the auxiliaries, such as the air brake pump and the headlight. The tender booster, operating up to 10 miles per hour, takes steam from the main superheater, reduced to between 150 lb. and 250 lb. pressure.

The total combined heating surface is 3 779 square feet, and that of the fire-box is 1 124 square feet without counting the arch tubes, so that the fire-box contributes no less than 29.8 % of the total. The grate area is 71.4 square feet, therefore the ratio of grate area to combined heating surface is 1 to 53.

The tender in general presents no unusual features. It runs on eight wheels, and the trailing end is carried by the booster. The fuel space takes

15 1/4 tons, and the tank capacity is 9 000 gallons. The booster tractive effort is 19 700 lb.

Performance and operating results.

The Horatio Alien was first run under its own steam on 20 May 1924, made its initial road test on the Delaware and Hudson on 28 June, and entered into road service on 16 August of that year.

The sustained capacity of this locomotive in compound gear has been well demonstrated on all its runs, thus far made, and the following notes are given relative to its performance on a 19 mile climb, having a predominating gradient of 1.42 %. The run was made in about 50 minutes, and the drawbar pulls ranged from 40 000 lb. to 57 000 lb. with a train of fifty cars of 1 327 adjusted tons.

Over the last 5 miles of the run the mean boiler steam pressure was 345 lb., the readings being the same at each mile post. The branch pipe pressures were 335 lb., those in the receiver 92 lb., and the branch pipe steam temperatures were 590° Fah.; whilst the drawbar pull averaged 46 000 lb. at a mean speed of 17 miles per hour. This latter figure shows that the engine developed and average of 1 840 drawbar horse-power, which would mean about 2 100 horse-power at the cylinders.

On the heaviest work on this gradient the coal consumption is stated to be well within the range of comfortable hand firing for an average fireman, and is but little more than that of two smaller superheated simple consolidations, which take 70 minutes to make the trip, with 1 885 adjusted tons, as against 50 minutes with 3 500 tons for the new engine.

Up to January 1925, this locomotive had made about 8 000 miles in regular service, with full load trains, and had given every satisfaction. It is as yet too early to report on the technical performance of the engine, as complete trials have not yet been made, and, furthermore, a feed heater and pump have not yet been fitted.

The only technical data available at the present time are given in the succeeding tabulation, which indicates, amongst other things, a satisfactory distribution of work in the high-pressure and low-pressure cylinders, a most important feature.

Working condition.	*Simple.*	*Compound.*	*Compound.*
Speed, miles per hour	6	15	20
L.P.C., I.H.P.:			
Hind end	276	434	494
Chimney end	272	445	488
Total	548	879	982
H.P.C., I.H.P.:			
Hind end	290	521	595
Chimney end	275	510	548
Total	565	1 031	1 143
H.P.C., cut off, per cent:			
Hind end	94	71.0	64
Chimney end	90	79.4	60
H.P. and L.P., total I.H.P.	1 113	1 910	2 125
Per cent. work in H.P. cylinder	50.8	53.9	53.7

In so far as the various novel constructive features of this locomotive are concerned, and especially the boiler, it is understood that up to the early part

of the present year no troubles were experienced — no leaks had developed either with the fire or water-tubes. This remark also applies to the cylindrical shell, water-leg headers, and to the upper and lower drums, and other boiler connections. The entire fire and heat insulation has also been satisfactory. The manhole joints in the upper and lower drums have given no trouble.

Whether or not a de-saturator is really necessary with this type of boiler, appears open to question, as the boiler carries its water level very well, and after a run of more than 500 miles, the condensate drained from the steam drier amounted to about one gill only.

The high steam pressure has not been the cause of any trouble with the valve and cylinder packing, bushings, or with the valve and piston-rod packing.

In general, the locomotive rides well, it moves easily over the track and coasts with freedom, and there has as yet been no evidence of serious engine shed or repair shop maintenance difficulties or expenses.

The photographs from which the illustrations have been made were kindly supplied by Mr. Muhlfeld, to whom the writer expresses his acknowledgments.

[656 .256 3 (.42)]

RE-SIGNALLING OF THE MERSEY RAILWAY

A comprehensive installation to meet increased traffic demands.

Figs. 1 to 17, pp. 138 to 149.

(*Modern Transport.*)

A new and interesting signalling system has recently been installed practically throughout the Mersey Railway. Opened in 1886, it was in 1900 that powers were obtained for the conversion of the line from steam to electric traction, a change which was accomplished in May 1903, and which represented the first instance of the substitution of electricity for steam in railway operation in this country. Connecting Liverpool and Birkenhead with outlying districts, the Mersey Railway, as will be seen from the map (fig. 1), begins at Liverpool Central (Low Level), the station being underneath that of the Cheshire Lines Committee, proceeds to James Street, and thence, under the River Mersey, to Hamilton Square, Birkenhead. Here it diverges, one branch extending to Rock Ferry, where there is an interchange station with the London Midland and Scottish and Great Western Joint Line, and the other to Birkenhead Park, where a connection is formed with the London Midland and Scottish Railway (Wirral Section), which feeds the residential districts of the Wirral Peninsula and the Great Central section of the London and North Eastern Railway. In « rush » periods, large numbers of passengers are carried between these stations, especially in the evening, when the great majority of city workers return to the Cheshire side of the river. During these hours as many as twenty-one trains per hour are

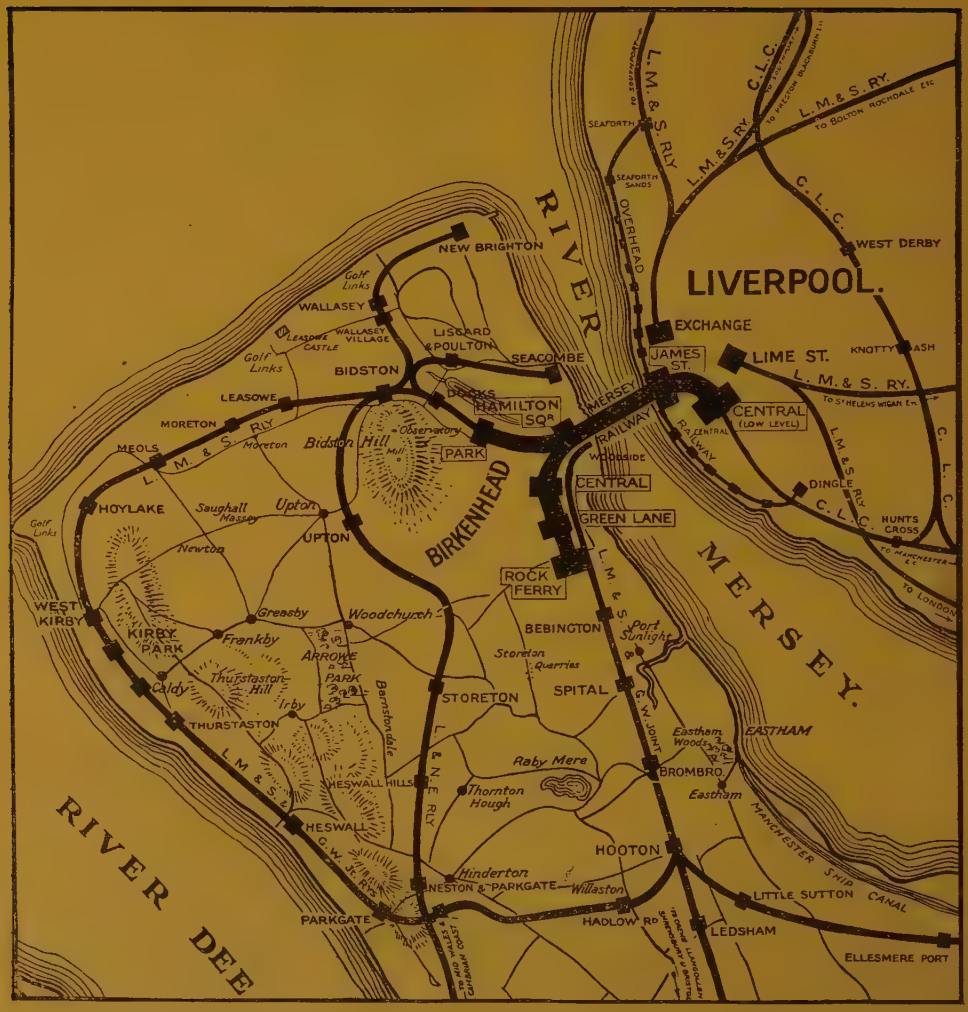


Fig. 1. — Sketch map of the Mersey Railway and its connections.

run, with a total of between 6 000 and 7 000 passengers per hour carried in one direction alone.

A great achievement.

The operation of this dense service was formerly achieved by means of mechanical signalling — a feat which redounds to the credit of Mr. J. Shaw, M. Inst. C. E., general manager and engineer of the company, and his staff — the problem of operation being accentuated by the physical characteristics of the line. The gradients from the lowest level under the centre of the river towards James Street and Hamilton Square are 1 in 27 and 1

Fig. 2. — Hamilton Square cabin before installation of electric signalling.

Fig. 3. — The cabin, as re-equipped, shewing power frame, illuminated diagram and telephones facing signalman.

Fig. 4. — Hamilton Square cabin, shewing relay and fuse cabinet.

in 30 respectively, and there are many others of equal severity, a profile of the line being shown in figure 7. Train working was, in addition, handicapped by the long, single block section of one mile, which existed between James Street and Hamilton Square stations. The time occupied in travelling through this section, with its long and steep gradients, limited the number of trains which could be run over the system. The method of overcoming this detrimental factor was the problem which first called for solution. As a result of investigation into the various systems of signalling which would accomplish the necessary speeding-up, and after an inspection, on similarly operated railways, by Mr. Shaw and his directors of various installations by the McKenzie, Holland and Westinghouse Power Signal Co., Limited — now associated with the Westinghouse Brake and Saxby Signal Co., Limited, of 82, York Road, King's Cross, N. — a contract for the work was placed with this firm by the Mersey Railway Company. Subsequent contracts for the resignalling of the remainder of the line were also placed with the Westinghouse Brake and Saxby Signal Company.

Arrangement of signals.

The accompanying diagrams illustrate the various sections of the railway as resignalled. By reference to figure 11, showing the section between Liverpool (Central) and Hamilton Square stations — a portion of the work which has already been described in *Modern Transport* — it will be seen that the track circuit divisions are indicated by marks on the lines. Signals S. 1, S. 2 and S. 5 are purely automatic : the remainder are semi-automatic, *i. e.*, automatics, but subject to control from their adjacent signal-boxes. There is an emergency cross-over road at James Street, which is worked by No. 6 lever in the signal-box there. This box, figure 6, is normally closed, but should emergencies arise that lead to the cross-over being required, the signalman would restore levers Nos. 3, 4 and 8 — shown reversed in figure 6 — which would hold signals C. 3, C. 4, and C. 8 at « danger », and allow the cross-over to be used. The signal for going through the cross-over road from the up to the down line is C. 11, which, besides being worked from the signal-box, is controlled by the down line track circuits ahead of the cross-over road. Before signal C. 11 can be « cleared », not only must No. 6 points be pulled, but also be bolted by No. 5 lever. Points and bolts are electrically detected by signal C. 11. Illuminated diagrams, indicating the position of the tracks in the immediate vicinity, are provided in each of the signal-boxes. The semi-automatic signals are electrically repeated into the boxes whence they are controlled.

The signals.

Colour light signals, of the flux neutraliser type, are used for the automatic signals in the tunnel, these having an upper red and lower green lens and no moving parts. The repeated signal RC. 3 has an upper yellow light. The red light is in duplicate, one behind the other. The front, or focal, lamp is supplied with current at approximately normal voltage, and the rear or reserve lamp is of a higher voltage. Whilst the latter is under-run, its voltage, should the front lamp burn out, would increase automatically to an amount sufficient to show a good red light in the signal. The low voltage circuit not only supplies, through a resistance, current to the two red lamps, but also to one winding of the flux neutraliser. The latter is the equivalent of a transformer, and connected in parallel with the lamps.

Effect of track relay.

On automatic signals the controlling contact is opened and closed by the track relay, and when the track circuit concerned is unoccupied the controlling con-

tact is closed and the « green », or high-voltage current passes through the green lamp, and, in series, through another winding of the flux neutraliser to the return. When the « green » circuit is open, current flowing through the « red » winding of the flux neutraliser creates a magnetic flux in the iron core, which, in turn, results in the winding having considerable impedance. When, however, the « green » is closed and current flows also through the « green » winding of the flux neutraliser, the latter is so connected and proportioned that the flux created in the iron core is equal and opposite to that created by the « red »

Fig. 5. — View of cabinet in James Street box.

Fig. 6. — Levers in James Street box.

winding. The light of the red lamps is thus suppressed when the green is alight. Moreover, the « red » circuit being fed at a lower voltage, it is impossible for this circuit to illuminate the high voltage green lamp. The windings of the flux neutraliser are so proportioned that even if the maximum « red » circuit voltage were applied to the « red » winding, the transformer action of the flux neutraliser could not produce a voltage in the « green » circuit higher than approximately one-third the voltage for the green lamp.

James street signal-box.

A view of the cabinet in James Street box, containing the controlling relays for tracks in the vicinity, is shown in figure 5. In the bottom compartment are situated the control fuses, which are fitted on all outgoing and incoming lines. On the left are seen the 100-volt bus bars, and on the right the 12-volt bus bars, the former feeding the various circuits for relay locals, signals and train stops, and the latter the « red » circuits for the signals. These bus bars are energised

from a main fuse and transformer set fixed in the cabin basement.

Train stops.

An ingenious type of train stop has been in use on the Mersey Railway since 1912. It is fixed outside the down side running rail, as in figure 17, and has a vertical movement. Normally the stop is down, and will clear the tripping apparatus on the train. With the signal at « danger » the stop is raised; should the motorman over-run the signal, therefore, the trip would strike the stop and the train would be automatically pulled up. The train stops are automatically held in action by means of a spring, and when it is necessary to put them out of action, air is automatically admitted into a compressed air cylinder and forces a piston in a position which overcomes the pressure of the spring. The release of air from the cylinder causes the spring to return the train stop to the « in action » position. The admission and release of air to and from the cylinders is effected by means of the corresponding track circuits. These train stops are used throughout the signalling installation. They were originally all-electric, but were converted by the contractors to the electro-pneumatic type. It is a point of interest that, with the exception of the vertical moving member, which is Mr. Shaw's own design, they are similar to those fitted on all the London tube railways.

Automatic points.
Interesting innovation

Following the installation of automatic signalling between Liverpool (Low Level) and Hamilton Square stations, the mechanical signalling at the former station remained, « SYX » lock and block instruments being fitted in cabins A and B. To meet increasing traffic requirements, however, it was decided to go a step further and embark on a novel enterprise, one, in fact, which had not apparently been so far attempted on any railway. This was the installation of apparatus which would provide for the automatic operation of a cross-over road and a pair of catch points, with their necessary signals, as shown in figure 9, the work being completed and passed for traffic on 4 February 1923. In this connection the electro-pneumatic principle was adopted for the first time on the Mersey Railway. This system was chosen because a supply of air, used for charging the brake equipment of the trains, was already available, and because of the simplicity of the device.

Method of working

Trains from and to Birkenhead arrive at and depart from the west end of the station, while at the east end Nos. 1 and 2 platform roads are extended to form Nos. 1 and 2 sidings. A cross-over (A7) is provided to enable empty trains to shunt from No. 2 platform road to either Nos. 1 or 2 sidings, and is so situated that a train arrives and stops at No. 2 platform just clear of the cross-over road. An arrangement with a time element in the control is installed, which takes from 20 to 30 seconds to operate, and ensures that the train remains within a certain section of the platform road for a definite time, this time being of sufficient length to ensure that the train shall have come to rest. At the expiration of this time the cross-over is reversed, and the signal is cleared for the train to run into No. 1 siding. When this train is in the siding the cross-over is again placed normal, and, provided that the other road (No. 1 of the island platform) and the overlap on starting signal B. 4 are clear of trains, a pair of catch points are reversed, and the signal reading into this road is « cleared », so that the train may be reversed and brought to No. 1 platform, ready to load passengers for Birkenhead. For this train movement no human operator is necessary in the signal

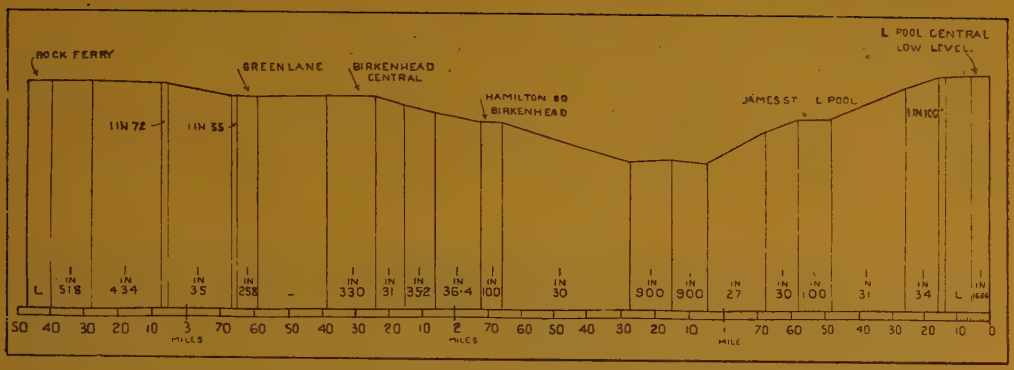


Fig. 7. — Gradient diagram, Mersey Railway.

Fig. 8. — Relay and fuse cabinet, cabin « B », Liverpool Central (Low Level) Station, Mersey Railway. Time element relay for working of B8 cross-over in centre of photograph.

cabins, but, should it be desired at any time to operate the points manually, it can be done by altering the position of a lever installed in the signal cabin, when the automatic working is put out of service and manual operation must be employed for the movement of points and signals.

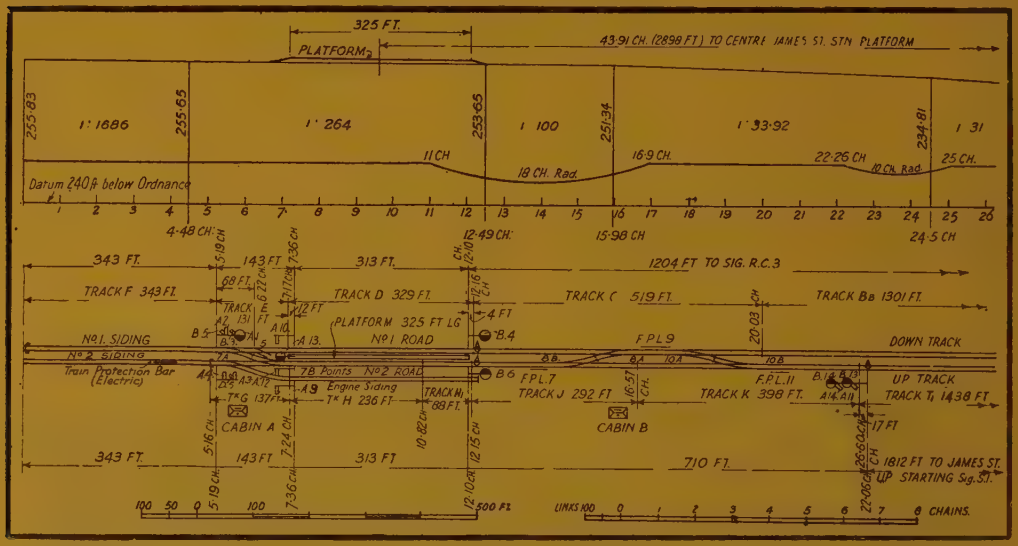


Fig. 9. — Arrangement of new automatic signalling between cabins « A » and « B » at Liverpool Central (Low Level) Station, Mersey Railway.

REFERENCE.

Cabin A.

Lever.	
1.	No. 1 siding to No. 1 road.
2.	No. 1 siding to No. 2 road.
3.	No. 2 siding to No. 2 road.
4.	No. 2 siding to engine road
5.	Trap points (spring).
6.	Mechanical points (spring).
7.	Crossover from No 2 road to No. 1 siding.
8.	King lever.
9.	Engine siding to No. 2 siding.
10.	No. 1 road to No 1 siding.
11.	Slot lever to No. B 13 signal.
12.	No. 2 road to No. 2 siding.
13.	No. 2 road to No. 1 siding.
14.	Slot lever on B 14 signal.
15.	Spare.
16.	Spare.

Cabin B.

Lever.	
1.	Spare.
2.	Spare.
3.	Slot to signal A. 1.
4.	Down starting signal from No. 1 road.
5.	Mechanical slot to signal A. 2, and A. 3.
6.	Down starting signal from No. 2 road.
7.	Bar on 8 B.
8.	Crossover, up to down road.
9.	Bar on 8 A und 10 A.
10	Crossover, up to down road.
11.	Bar on 10 B.
12.	King lever.
13.	Up home to road No. 1.
14.	Up home to road No. 2.

Extension of automatic point operation.

It was subsequently decided to extend the principle of automatic operation to cross-over B. 8 at the west end of the Liverpool terminus, these points being also shown in the diagram, figure 9. The apparatus, which was brought into operation on 10 August 1924, enables passenger trains to depart to Birkenhead, via No. B. 8 cross-over, with cabins A and B closed, this method of working being normally used during periods of light train services; from personal inspection we can testify to its suitability for the working of trains into and out of the station at five-minute intervals. The cross-over points are operated and lock-

ed by compressed air in a manner similar to that in operation at No. A7 cross-over at the east end of the station, already referred to. This second cross-over, however, embodies an improvement in the shape of a cut-off valve, the circuit for this being so arranged that when a train is approaching the cross-over, the air supply to the points is cut off : thus, even should an attempt be inadvertently made to energise the wrong valve, the points would not respond, as there is no air to do the work. A further refinement is the fitting of an electric lock to the facing point lock plunger. Figure 10 gives a general view of the automatic point mechanism at B.8 cross-over, whilst figure 15 illustrates the valves controlling the admission of air in connection with the working of the cross-over.

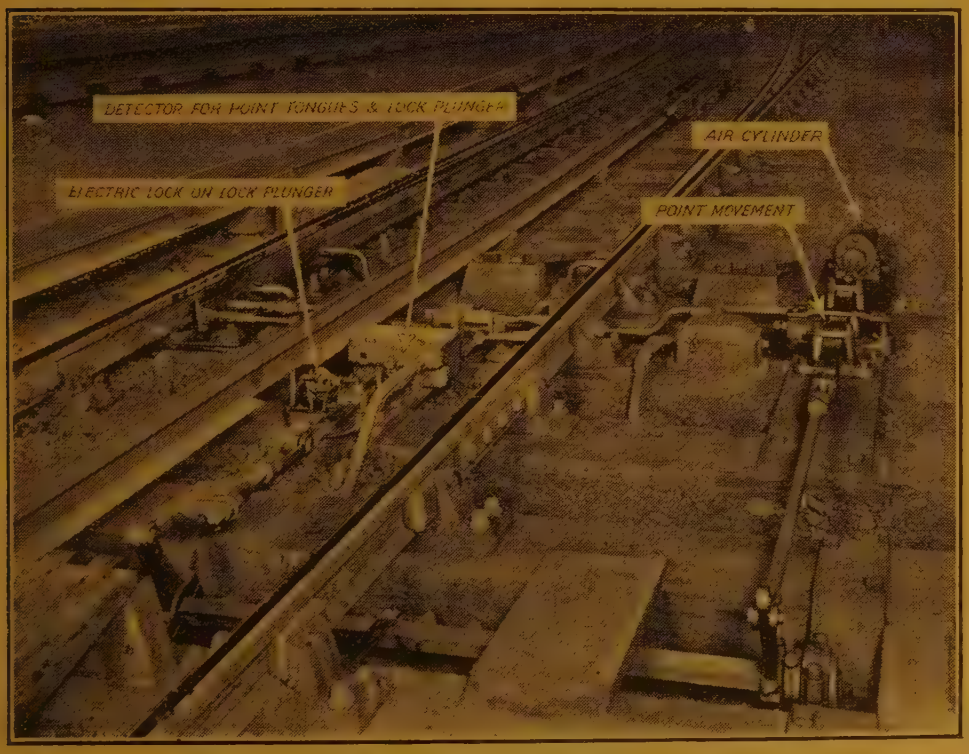


Fig. 10. — Automatic point mechanism, B8 cross-over, at west end of Liverpool Central (Low Level) Station, Mersey Railway, the covers having been removed.

Working of B. 8 cross-over.

No. B.8 cross-over points automatically throw from the normal to the reverse position when a train arrives at No. 2 platform, *i. e.*, when occupying H. and H.1 track circuits, and track circuits J, K, C, and D are clear, and, provided that the down line is clear up to and including track circuit A.c (the overlap track circuit to James Street down home signal), signal B.6 shows a green light and the

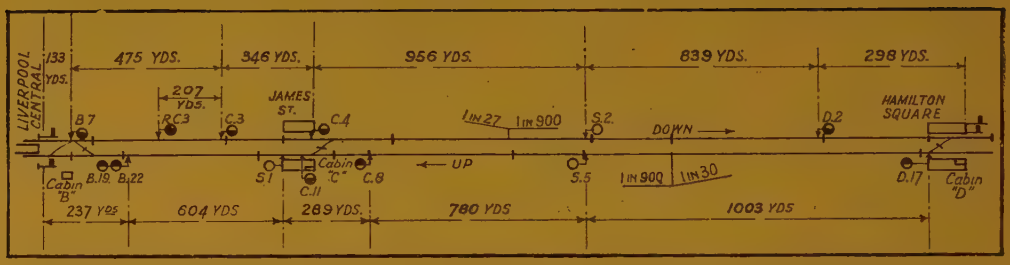


Fig. 11. — Diagram shewing automatic signalling between Liverpool (Central) and Hamilton Square Stations, Mersey Railway.

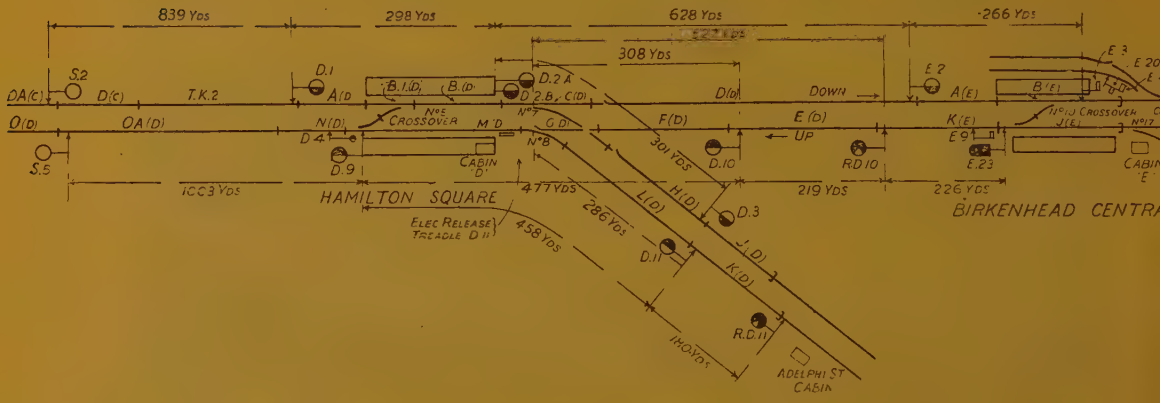


Fig. 12. — Diagram shewing extension of automatic signalling, Hamilton Square to Birkenhead Central and Adelphi St

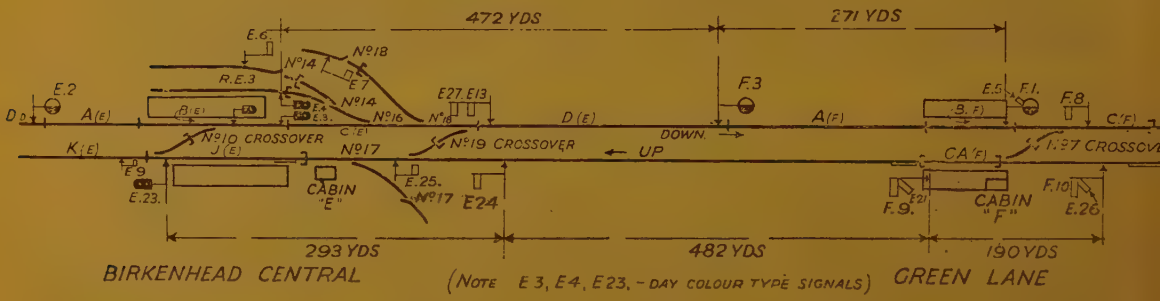


Fig. 13. — Diagram shewing further extension of automatic signalling, Birkenhead Central to Green Lane.

train stop thereto will assume the « out of action » position. This train stop returns to the « in action » position when a departing train reaches B track circuit. The cross-over points revert to the normal position as soon as a departing train has cleared C track circuit, and providing the track circuits K, J, C, D, H, and H.1 are unoccupied, signal B.14 shows a green light and the train stop at signal B.6 assumes the « out of action » position to allow the following train to enter the station. Incidentally, when a train is standing at No. 1 platform, *i.e.*, on D track circuit, the automatic working of No. B.8 cross-over cannot be used. The train stop fitted at signal B. 6 assumes the « in action » position immediately a train has arrived at No. 2 platform, provided the track circuits between signal B14 and the platform pick up in the normal way, and remains in this position until signal B.6 shows a green light to allow the train to proceed to James Street. In the event of J or K track circuits failing to pick up, the cross-over would not reverse, and arrangements have been made for the train stop to assume the « in action » position approximately 30 seconds after the arrival of a train at No. 2 platform. For the purpose of switching in and switching out the automatic working at A.7 and B.8 cross-overs, special levers are installed in signal-boxes A and B. Figure 8 gives a view of a portion of the relay cabinet in cabin B, Liverpool Central (Low Level).

Further extensions.

28 October 1923, marked the opening of a further extension of the automatic signalling, namely, from Hamilton Square Station to Birkenhead Central Station on the main line, and approximately, to Adelphi Street cabin (which was dismantled) on the branch line, the new lay-out being shown in figure 12, whilst interior views of Hamilton Square box are given in figures 2, 3 and 4. At Hamilton Square electro-pneumatic point operation was decided upon because of the very satisfactory service the electro-pneumatic points and train stops had given at Liverpool Central. The mechanical frame in Hamilton Square cabin (D) was replaced by a power frame (fig. 3) which electrically controls the signals, train stops and points, the junction points (D.7 and D.8) and Hamilton Square station cross-over (D.5) being power-operated by compressed air. Each lever is mechanically interlocked and fitted with electric locks operated by the track circuits. Finally, on 9 March 1924, the sections between Birkenhead Central Station and Green Lane Station, on the main down line, and between the location of the former Adelphi Street cabin and Birkenhead Park Station, on the branch up line, were similarly equipped, as shown in the diagrams, figures 13 and 14. Two of the standard day colour light signals at Birkenhead Central are shown in figure 17, as also two of the new electro-pneumatic train stops.

Power supply.

Direct current being used for traction, the signalling is alternating current. Two motor alternator sets, each of 5 k.v.a. capacity, and a signal switchboard were supplied by the Lancashire Dynamo and Motor Co., Limited, as sub-contractors, and fixed by the signal contractors in the railway company's power house. The motor is a shunt-wound four-pole machine running off D.C. supply, which may vary between 500 and 700 volts, coupled direct to an alternator of the revolving armature type. The 600-volt single-phase 50 cycles signal supply is transmitted to transformers fixed at intervals to the walls of the tunnel, and is transformed down to the necessary voltage for operating signals, train stops and track relays. Each transformer has one primary winding 550/600 volt, and two separate secondary windings, giving 100 volts and 12 volts. A 6 volt tapping is taken of the 12 volt secondary coil.

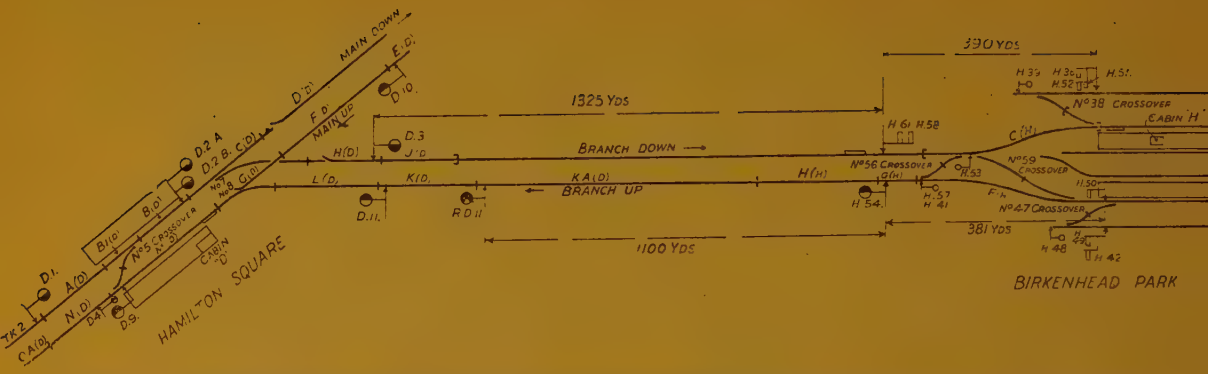


Fig. 14. — Diagram shewing further extension of automatic signalling, Adelphi Street to Birkenhead Park Station.

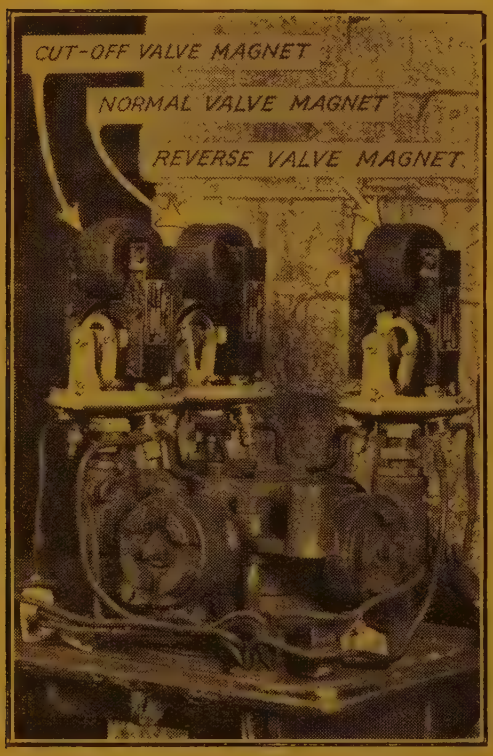


Fig. 15. — Valves controlling admission of air in connection with operation of B8 cross-over, Liverpool Central (Low Level) Station, Mersey Railway (cover removed).

Fig. 17. — Automatic day colour light signals, E4 and E3, Birkenhead Central Station, shewing also automatic train stop mechanism with covers removed.

Track relays.

The track relays are of the well-known two-element vane type, and are provided with two windings, local and track. The local winding is constantly energised at 100 volts, and the track element, operating at a low voltage, depends on the conditions of the track circuits for its energy. These relays are of the latest type and quite immune to operation by D.C. It has generally been the practice of the contractors to supply a resistance or impedance, in series with the track transformer, in order to limit the short circuit current to the track circuit when a relay is shunted. The conditions prevailing here were such, however, that this course in many cases was impossible. Naturally, an amount of salt water from the river above had percolated through the ballast, which reduced the insulation resistance of the ballast to an almost negligible amount, so much so that special means of feeding the track circuits were necessary.

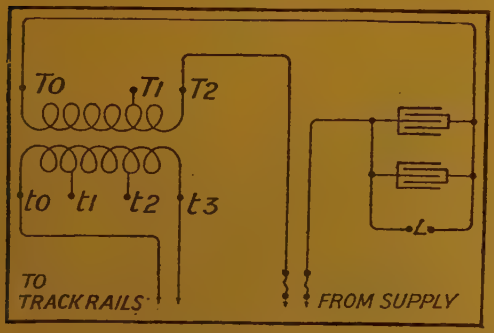


Fig. 16. — Condenser feed track service set, Mersey Railway.

Condenser feed track circuit system.

To overcome this difficulty the contractors installed their patent condenser feed track circuit system, figure 16. This type of track circuit requires a special transformer, with a primary winding feed from the 100-volt mains through an adjustable condenser, and a secondary winding connected direct to the track rails. Regulation is effected by means of tapping on the transformer windings and also by varying the capacity of the condenser, the latter being adjustable for this purpose. By using the tappings on the transformer windings the phase angle can be adjusted to either lead or lag as desired. This system is very economical, the watts taken for the track circuit with a train in section being less than are taken with a clear track. An idea of the low ballast resistance obtaining may be gathered from the fact that on a short track, 367 feet in length, the ballast resistance was only 0.105 ohms. This is exceptional and it is possible there are no other track circuits in existence working under such difficult conditions. All this equipment is kept in cast-iron cases, and is therefore free from the ill-effects of the atmosphere of the tunnel.

Conclusion.

In expressing to Mr. Shaw, the general manager and engineer of the Mersey Railway, our appreciation of the courtesy extended to us during our inspection of the new signalling for the purposes of the present description, we would venture to offer our congratulations on the courage and enterprise he displayed in taking steps, in conjunction with the contractors, the Westinghouse Brake and Saxby Signal Co., Limited, which led to the installation of automatic points for the handling of heavy passenger traffic. As previously indicated, we believe that this is the only railway in the world possessing an installation of this character. Startling though the innovation was, the Ministry of Transport were not slow to afford to the railway company and the contractors every assistance and co-operation in connection with the scheme. The subsequent satisfactory operation of the points under heavy traffic conditions has afforded proof of their ability, not only to answer all requirements from the point of view of safety, but to ensure maximum economy in daily working.

MISCELLANEOUS INFORMATION

[625 .143.5]

1. — Rail creep,

By E. GUIRAUD,
MANUFACTURING ENGINEER.

Figs. 1 to 3, pp. 151 and 152.

(*Les Chemins de fer et les Tramways.*)

Under the various effects to which the track is subjected, experience has shown that the rails at certain places have a tendency to move longitudinally if no precautions are taken to fix them.

The importance of this phenomenon, which is known as « rail creep », is dependent upon the lay-out and gradient of the line, the speed, weight and frequency of the trains, whether brake applications are frequently made at any particular spot, this being of course dependent on the position of signals or stations.

The normal method of attaching the rail, either by spikes or coach screws in the case of the Vignoles rail, or by keys in the case of the double headed chaired rail, does not in practice form a sufficient restraint to the tendency of the rail to creep at certain points in the road.

By reason of the increase in traffic, and in the tonnage and speed of trains, rail creep is at the present time, under certain circumstances, of considerable importance. The rails are found on very considerable lengths of line to be closed up end to end, so that the effects of expansion cannot be properly taken up, and this renders it difficult to keep the track in proper alignment.

The railway companies have therefore been compelled to supplement the ordinary method of attaching the rail, which is only suitable for resisting forces in a perpendicular direction, by an anchorage device fixed to the sleepers, which resists longitudinal forces and which overcomes the difficulty due to creep, and thereby allows free expansion of each rail length.

We will now proceed to examine the various devices used for this object.

The Paris-Lyons-Mediterranean Railway use a special metal device known as a stop plate. It consists of a rectangular plate bent to an « L » shape, being fixed to the rail by a bolt; the lower part forms a sole plate for the foot of the Vignoles rail.

The screwed spike is passed both through the ordinary fastening of the rail and the stop plate.

The rail is thus very efficiently anchored.

One, two or three stop plates may be used in accordance with the length of the rails and local conditions, these being fitted to the sleepers under the middle of the rail.

The State Railways have also adopted, for their Vignoles rails, a stop plate similar to that used on the Paris-Lyons-Mediterranean.

The Eastern Railway of France, in order to overcome rail creep, use angle plates fixed to the rail by a bolt and fastened by two screwed spikes to the sleeper.

The Midi Railway use suspended fish plates which bear against the chairs on either side of the joint.

The length of these fish plates and the space of the joint sleepers are so arranged to give a minimum amount of play for longitudinal displacement of the fish plate.

This arrangement of suspended fish plates is also used for certain types of double headed rails on the State Railways, as is also a very heavy type of fish plate known as the bridge type, which is used with 85.16 lb. double headed rails.

This latter arrangement consists of a fish plate provided with a bottom flange spiked to the joint sleepers, which, in addition to giving very high resistance, as opposed to transverse forces, also provides very efficient anchorage.

The Alsace-Lorraine Railways employ stop brackets bolted to the web of the rail with a

downward projecting portion which bear on the sleepers on metal plates nailed on the latter with the object of preventing the wood from being worn away where it comes into contact with the brackets.

The foregoing « anticreep » devices have, however, the following disadvantages :

On the one hand the stop plates and projecting brackets necessitated additional holes being drilled in the rails, which certainly increases the chance of breakage, the holes drilled in the web having in any case an obviously undesirable effect upon the rail.

Moreover, where brackets with a downward projection are used, the transmission of the force from the rail to the sleepers is effected under undesirable conditions on too small a surface.

Finally, the suspended fish plates or bridge type fish plates do not present an entirely satisfactory solution as regards resistance to rail creep. They can be only applied to two sleepers per rail length; this may perhaps be sufficient in certain cases, but one has to use other additional devices in cases where the amount of creep is considerable.

The « Winby » anticreep device.

Certain French companies, the Northern, Eastern, Paris-Orleans and the Paris-Lyons-Mediterranean in particular, have for some time used the Winby « anticreep » device, which is used on a considerable scale in England and in the United States, and which overcomes the disadvantages of the preceding devices.

Figure 2 shows how the Winby device is fitted on the Vignoles type rail.

The Winby device consists of two pieces (fig. 1) : the attachment and the key, and does not necessitate the use of any bolt, screw, washer, wedge, or any other part which may work lose. These two pieces are so formed

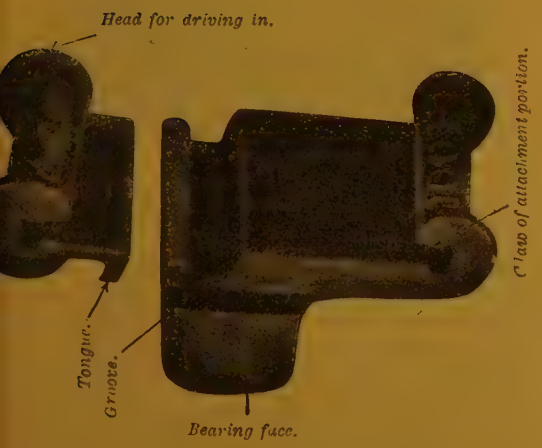


Fig. 1. — « Winby » anticreep device.

Fig. 2. — Perspective view of « Winby » anticreep device mounted on the rail.

that the action of rail creep is to tighten the wedging action on the foot of the rail. The more rail creep there is, the tighter will the device grip the foot of the rail.

The attachment is the larger of the two pieces; it is shaped to fit the rail and is provided with a groove in which fits the tongue of the key, and has a bearing surface which bears against the sleeper and is of sufficient depth to avoid any tendency to turn over the sleeper, which invariably happens if the depth is too little.

The key performs a very important part, as it holds the rail in place. It is formed to fit the foot of the rail, and is provided with a tongue which engages in the groove in the attachment, and has a strengthened face upon which to take the blows of the hammer used to force it into position.

These two portions are made of cast steel, and show on the upper part an indication of the type and weight of the rail for which they are intended.

Assembling these on the rail is very simple, and only necessitates the use of a 3 1/2 to 4 1/2 lb. hammer.

The attachment is placed on the foot of the rail, as in figure 3, with the bearing face against the sleeper, and a blow is then struck at the back so as to drive the bearing face up to the sleeper and to ensure that it is properly placed on the foot of the rail. The key is then placed on the foot of the rail and is struck by blows of the hammer in an oblique direction towards the rail and towards the sleeper, the tongue of the key having been fitted in the groove in the attachment. When properly fitted, the key should engage for half its length in the attachment (fig. 3) and no play should exist between the vertical faces of the foot of the rail and the jaws on the two portions.

The Winby apparatus as made for a double headed rail is similar in principle to the above.

In order that this device may be effective in preventing rail creep, it is necessary that the bearing face should be in contact with the sleeper over the greater part of its height.

The tendency for the rail to creep being transmitted by these devices to the sleepers, it is the sleepers themselves which oppose the creeping action. The resistance offered by the sleepers to their displacement in the ballast should be greater than the force resulting from the tendency of the rails to creep.

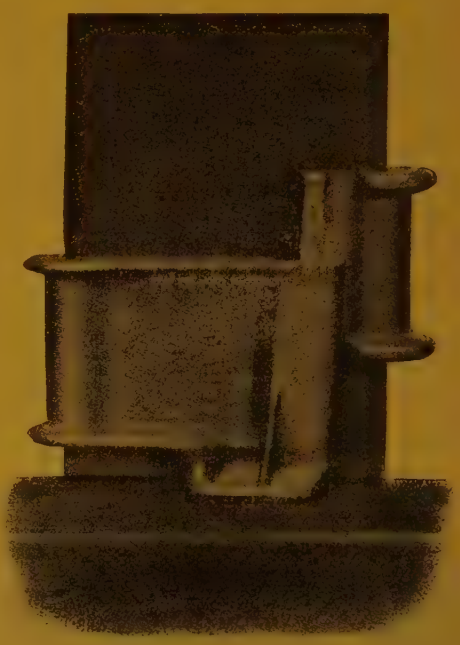


Fig. 3. — The « Winby » device in place on the rail seen from below.

The number of these devices to be placed on each length of rail depends upon the amount of rail creep which takes place, and on the resistance which the sleepers offer to displacement. As a rule, four to six Winby devices are sufficient.

The results obtained for a number of years on a considerable mileage of important lines have shown the efficiency of this device, which is, moreover, very economical as compared with the other devices fitted to prevent rail creep.

[621 .132.5 (.42)]

.2 — Two new types of locomotive on the London & North Eastern Railway : A « Garratt » locomotive and a « Mikado » type locomotive.

Figs. 4 and 5, p. 154.

(From the *Railway Gazette.*)

Those who attended the Railway Centenary celebrations at Darlington had an opportunity of seeing, side by side with George Stephenson's locomotive of 1825, two very interesting engines built for the London & North Eastern Railway.

These two engines, a *Garratt* for banking and a *Mikado*, built to the design of Mr. H. N. Gresley, chief mechanical engineer of the Company, constitute two innovations on British railways, where locomotives of these types have not previously been used. They also show a development of the three high pressure cylinder system, well known in England. On the *Mikado* we find a *booster*, already used in America, and which in England first made its appearance on an *Atlantic*.

We quote from the *Railway Gazette* of 26 June 1925 the following details of these two engines.

« Garratt » locomotive (fig. 4).

The London & North Eastern Company's Garratt locomotive has been designed for working heavy coal trains on the Worsboro' bank between Wath and Penistone, a distance of 7 miles, where there is a gradient of 1 in 40 for two miles. The loading of these trains is about 1 000 tons. They are at present worked by two train engines in front and two or three banking engines in the rear.

The *Garratt* is to replace these latter.

This locomotive is remarkable for its powerful boiler (barrel 7 feet diameter, grate area 56.4 square feet). It is actually the most powerful and heaviest engine in use in England. The tractive force, calculated at 85 % of the boiler pressure, is 72 940 lb.

The engine has six cylinders, three to each unit. Walschaerts gear is used for the valves of the outside cylinders, the inside being operated by Mr. Gresley's system of horizontal levers. As many parts as possible (cylinders, connecting rods, etc.) have been made interchangeable with those of the eight-wheeled coupled three cylinder locomotives of the London & North Eastern Railway.

The total weight of the engine is 178 t. 3 qr., and the maximum axle load does not exceed 18 t. 6 cwt. 2 qr.

The following table gives the principal dimensions of the engine :

Cylinders (6), diameter . . .	18 1/2 inches.
— piston stroke .	26 inches.
Wheels, coupled, diameter. .	4 ft. 8 in.
— bogie, diameter . .	2 ft. 8 in.
Boiler barrel, length	13 feet.
— — diameter. . . .	7 —
Small tubes, number and dia.	275 — 2 in. dia.
Large — — —	45 — 5 1/4 in. dia.
Heating surface, tubes. . . .	2 757 square feet.
— — firebox. . .	237 — —
— — total	2 994 — —
— — superheater.	646 — —
Grate area	56.4 — —
Working pressure.	180 lb. per sq. inch.
Tractive effort (at 85 °/o) . .	72 940 lb.
Ratio of adhesive weight to tractive effort	1 : 4.37.
Wheelbase of coupled wheels.	17 ft. 10 in.
Total wheelbase	79 ft. 1 in.
Tank capacity	5 000 gallons.
Coal —	7 tons.

« Mikado » locomotive (fig. 5).

The *Mikado* locomotive is designed for working trains of 100 wagons, having a load of about 1 600 tons, between Peterborough and London, where the *Consolidation* type engines, recently introduced by Mr. Gresley handle loads of about 1 280 tons (80 wagons). The diameter of the coupled wheels has been raised from 4 ft. 8 in. to 5 ft. 2 in. in order to increase the speed.

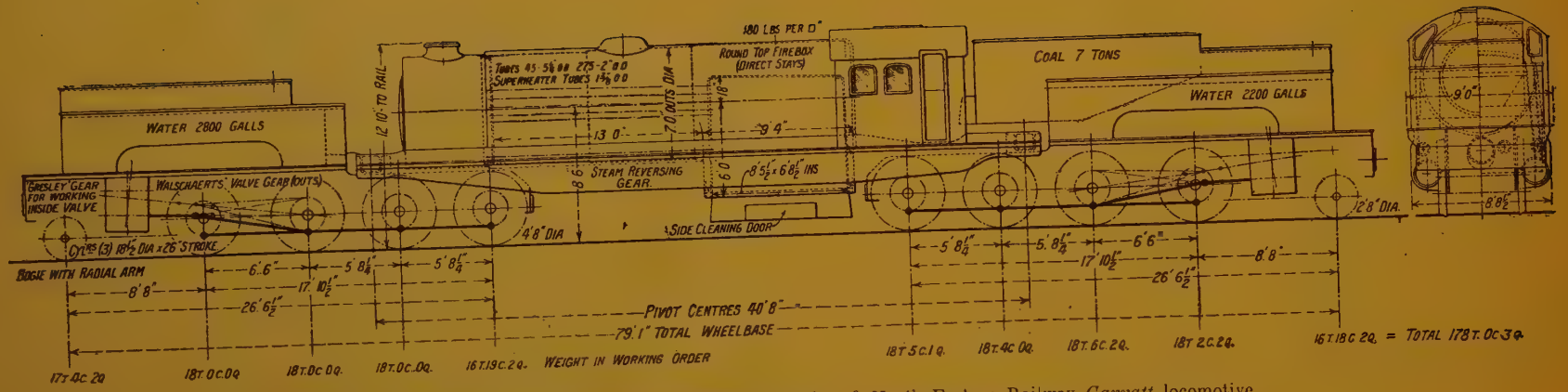


Fig. 4. — Diagram showing general proportions of London & North Eastern Railway *Garratt* locomotive.

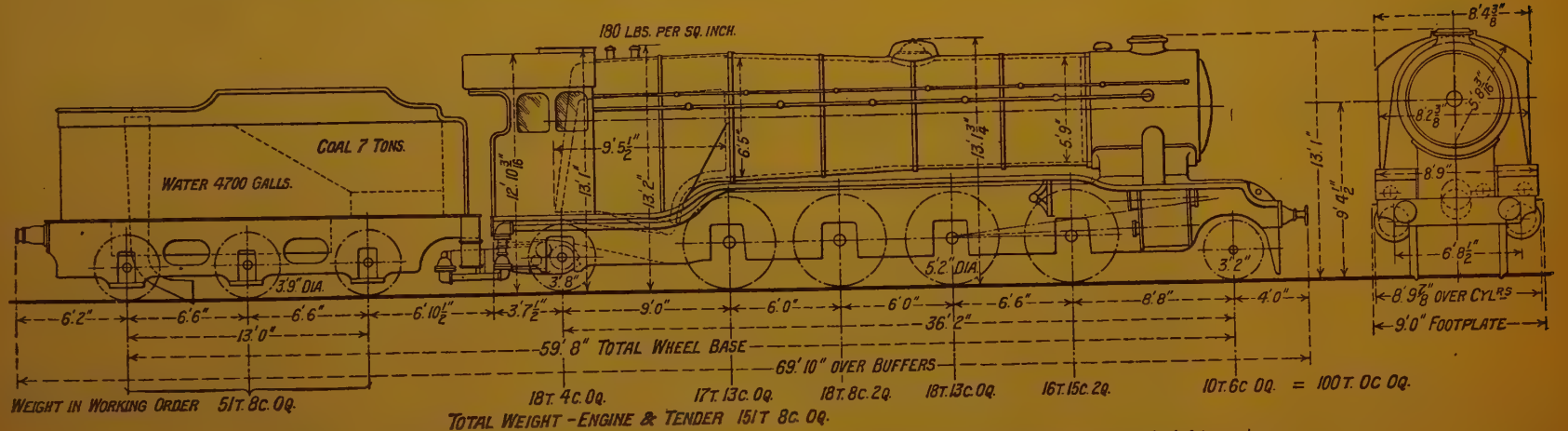


Fig. 5. — Diagram showing leading dimensions of London & North Eastern Railway 2-8-2 type freight engine.

This engine also has three cylinders with the same valve gear as that described above. In its construction a number of parts identical with those of the *Pacific* locomotives have been used, notably the boiler, cylinders, valves, valve gear, etc.

The tender is fitted with paper pick-up gear.

The *booster* has been fitted for acceleration on starting and to enable the trains to be worked over long gradients of 1 in 200.

The following table gives the principal dimensions of the engine :

Cylinders (3), diameter	20 inches.
— piston stroke	26 —
Wheels, coupled, diameter	5 ft. 2 in
— leading, diameter	3 ft. 2 in.
— trailing, diameter	3 ft. 8 in.
Wheelbase, coupled	18 ft. 6 in
— total engine	36 ft. 2 in.
— total engine and tender	59 ft. 8 in.
Boiler length	19 feet.
Boiler, diameter	6 ft. 5 in.
Heating surface, tubes	2 715 square feet.
— — firebox	215 — —
— — total	2 930 — —
— — superheater	525 — —
Grate area	41.25 — —
Working pressure	180 lb. per sq. inch.
Tractive effort (at 85 % without *booster*)	38 500 lb.
Ratio of adhesive weight to tractive effort	1 : 4.16.
Booster cylinder, diameter	10 inches.
— — stroke	12 —
Tractive effort of *booster*	8 500 lb.
Ratio of weight to tractive effort	1 : 4.79.
Weight of engine in working order	100 tons.
Weight of tender in working order	51 tons 8 cwt.
Water capacity	4 700 gallons.
Coal capacity	7 tons.

[621 .335 (.73)]

3. — Baldwin 1 000 H. P. Diesel-electric locomotive.

Figs. 6 and 7, p. 156.

(*Railway Age.*)

A Diesel-Electric locomotive has been built by the Baldwin Locomotive Works, Philadelphia, Pa., which has the largest horsepower capacity of any internal combustion locomotive yet built in this country and has been approached in horsepower capacity by only one such locomotive; namely, the Lomonosoff locomotive (1) built in Germany for the Russian government. The Lomonosoff locomotive is driven by a four-cycle engine which is reported to have developed 1 100 H. P. on the test plant.

The rated maximum tractive force of the Baldwin locomotive is 52 200 lb., the oil engine having a rated capacity of 1 000 H. P. The total weight of the locomotive is 275 000 lb., of which 180 000 lb. is carried on the driving wheels. The total length over the couplers is 52 ft. 1 3/4 in. The locomotive has a total wheel base of 38 ft. 4 in. and a rigid wheel base of 12 ft. 8 in. The electric transmission consists of four Westinghouse type 353-D-3, standard railroad type, self-ventilating 200 H.P. motors which are geared to the driving axles through flexible gearing. Power is furnished to these motors by a Westinghouse self-ventilating, direct current generator and exciter directly connected to the engine.

Referring to the illustration showing the side view of the locomotive, it will be noted that the general appearance is similar in many respects to that of an electric locomotive. The cab is of all-steel construction and extends the entire length of the frame. The height from the rail to the top of the cab is 14 ft. 7 in. and the width overall is 10 ft. 5 in.

The power plant of the locomotive is carried on two six-wheel trucks, each made up of the

(1) This locomotive was described in the *Railway Age* of 31 January 1925, p. 321.

Fig. 6. — 1 000 H. P. Diesel-electric locomotive built by the Baldwin locomotive works.

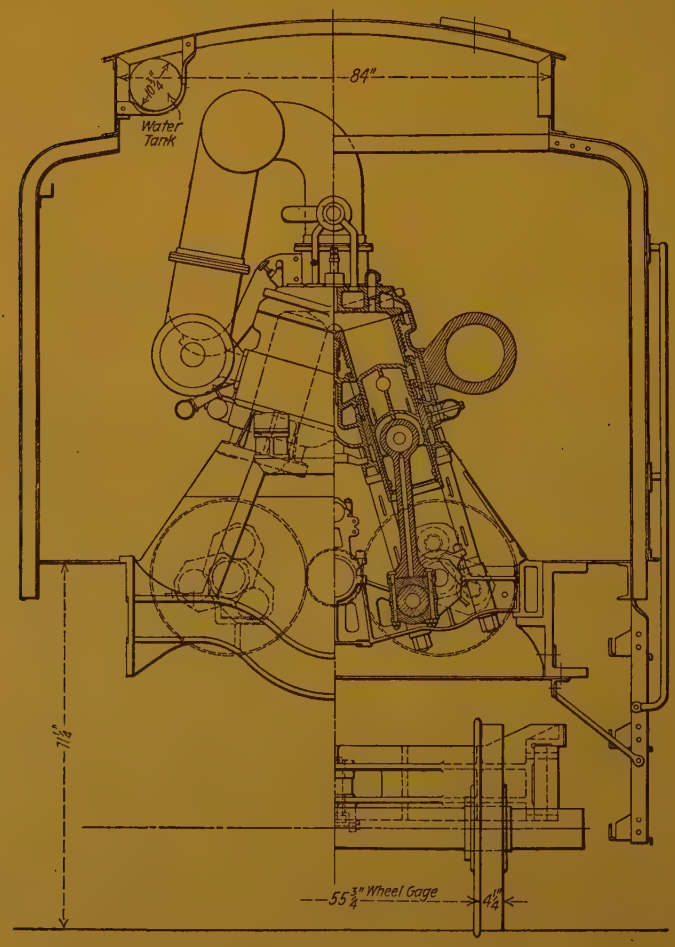


Fig. 7. — Cross section through the locomotive, showing a section through one of the oil-engine cylinders. The scavenging air manifold is shown at the left and a section through the exhaust manifold is shown at the right.

usual locomotive type bar frames in the pedestals of which are mounted outside journal boxes of three pairs of wheels. The two motors in each truck are geared to the outside axles, the middle pair of wheels running idle. The power plant, consisting of the oil engine, the direct-connected generator and the auxiliaries, is carried on two longitudinal cast steel girders which are connected by cast steel cross-ties at each end. These cross-ties also contain the center pins which engage the center plates of the two motor trucks. The drawbar pull is transmitted from one truck to the other through a drawbar and radial buffer construction at the inner ends of the two trucks, of a type commonly used in electric locomotive design.

A feature in the design of this locomotive is the arrangement of the spring rigging which has been patented by the builder. Two springs are placed over each box, one on the inside and one on the outside of the frame, each resting directly on top of the journal box and connected with each other by short cross equalizers at each fixed attachment to the frames. These equalizers allow for any variation in the height or deflection of the two springs which act together. Placing the spring alongside of, instead of over the top of the frame as would be required by the usual arrangement of one spring for each journal box, permits the lowering of the center of gravity of the locomotive at least six inches and also permits a corresponding increase in the headroom in the cab.

The Diesel engine.

The oil engine, which is of the two-cycle solid injection type, was built entirely in the shops of the Baldwin Locomotive Works according to an arrangement with the Knudsen Motor Corporation, New York. There are twelve cylinders arranged in two groups of three pairs each, the pistons in the two cylinders of each pair driving on separate parallel crank shafts. Each pair of cylinders, however, has a common combustion space, enclosed by a single head casting and supplied with fuel through a single injection nozzle. The six fuel pumps, one for each combustion chamber, are operated by a cam shaft. In the center of each of the two crank shafts, between the two groups of cylinders, is a large herring-bone gear, the gears from the two shafts meshing with a herring-bone pinion on the end of the generator shaft which steps up the crank shaft speed of 450 revolutions per minute at the generator.

The cylinders, which have a diameter of 9 3/4 inches and a stroke of 13 1/2 inches, contain the ports usual in two-cycle internal combustion engines near the end of the stroke. The gears, which keep the two crank shafts in constant angular relationship, are so meshed that the pistons on one side of the engine are in slight angular advance in relation to those on the other side. Through the ports in these cylinders the exhaust takes place, to be followed by the admission of scavenging air from a manifold connected to the corresponding ports on the other side of the engine. The scavenging air thus enters through the ports in one cylinder and passes up through that cylinder, down through the other and out through the exhaust ports once in each revolution. On the return stroke the piston on the exhaust side of each pair of cylinders closes the exhaust ports slightly in advance of the closing of the air intake ports of the other cylinder so that scavenging air, which is delivered by a blower at about 2 1/2 lb. pressure, builds up to this pressure in the cylinders before the intake port closes and compression begins. In this way a degree of super-charging is effected which materially increases the amount of power that may be developed in a given cylinder volume.

Another special feature of the engine lies in the port openings in the cylinder and piston walls which permit air taken from the scavenging blower and boosted a few ounces in pressure through a small gear-driven fan, to blow through the closed chamber in the top of the piston above the wrist pin and mingle with the scavenging air in the cylinders, the purpose being to cool the pistons.

The Westinghouse 750-kw., separately excited, direct current generator develops 750 volts at 1 200 revolutions per minute, and is direct connected to the step-up shaft of the oil en-

gine, the increase in the speed of this shaft over that of the engine crank shafts permitting a material reduction in the generator weight.

The principal auxiliaries which form a part of the power plant are the scavenging blower, the water cooling system and the air compressors. The scavenging air is delivered by a centrifugal blower which is driven at 3 000 revolutions per minute by a gear connection to an extension of the generator shaft. This blower has a capacity of 4 500 cubic feet of air per minute at 2 1/2 lb. pressure. The water cooling system, which was designed by the Modine Manufacturing Company, Racine, Wis., consists of two radiators, one built into each end of the locomotive cab, the water being circulated by a gear pump driven from the engine shaft. Air is circulated through each radiator by a fan, the fan at the front end of the locomotive being driven mechanically from the engine shaft, while that at the rear end opposite the generator is motor driven.

The locomotive is equipped with three Westinghouse motor-driven traction air compressors. One of these is suspended under the cab at each end of the locomotive, while the third is mounted in the cab over the generator. Connected by means of a clutch to an extension of the motor shaft of this compressor is a small four-cylinder gasoline engine which is used in starting the locomotive to build up a main reservoir pressure of about 120 lb. to supply air to turn over the Diesel engine the few revolutions required before combustion takes place in the cylinders. The gas engine is then declutched and stopped, the compressor continuing to operate as a motor-driven unit under the same automatic control as the other two units.

The starting system consists of six air distributing valves operated by the cam shaft, each admitting air to its pair of cylinders through a check valve in the cylinder head. A single throttle admits air to all the distributing valves when the motor is to be started.

The lubrication of the engine is a combination of the force feed and splash systems, the oil circulating pump being driven mechanically from the engine shaft.

The control equipment.

The control equipment, which is of the Westinghouse electro-pneumatic type, is arranged for double end operation of the locomotive. With the Diesel engine and generator running at a constant speed, the locomotive is accelerated from standstill by the manipulation of a master controller by which the voltage of the generator is increased in steps, through field control, as the speed of the locomotive increases. With full generator voltage for a given generator speed developed in this way, further acceleration is effected by increasing the Diesel engine speed and, hence, the generator power output. The oil engine throttle is controlled by the manipulation of a valve handle on the master controller, which permits the increase or decrease of oil pressure in a cylinder, the piston of which in moving outward, compresses the governor springs. The throttle thus controls the speed at which the governor operates to reduce the stroke of the oil injection pump pistons. The unusual feature of this throttle control from the operator's standpoint, lies in the fact that it is manipulated to admit or release oil, supplied at constant pressure, to or from the control cylinder, only long enough to produce the desired engine speed, and is then brought to lap position until another change of power output is required.

Service trials.

The locomotive, which was built in June, 1925, has for some time been in service on the Reading, part of the time in road freight service, between Reading, Pa., and Tamaqua, and part of the time in yard service. In both services the locomotive has given a good account of itself from a mechanical and power standpoint, the high tractive force characteristic of a constant power output machine adapting it particularly well to heavy switching service.

While no attempt has yet been made to test the locomotive accurately in actual service, the following operating results have been obtained. The locomotive has handled 1 000-ton trains from Reading to Tamaqua, a distance of approximately 40 miles, about three-quarters of which is upgrade at the rate of about 0.7 %

with an average of 3.3 gallons of fuel oil per 1 000 gross ton-miles. It has moved these trains over the grade at a speed of approximately 16 miles an hour. On the runs in the reverse direction, with 2 000-ton trains, the fuel consumption averaged one gallon per 1 000 gross ton-miles.

The block tests of the engine indicate a fuel consumption of 0.40 gallons per horsepower hour at full load, increasing to 0.45 gallons per horsepower hour at half load. The engine has developed a maximum crank shaft speed of 480 revolutions per minute. It operates smoothly with very little vibration.

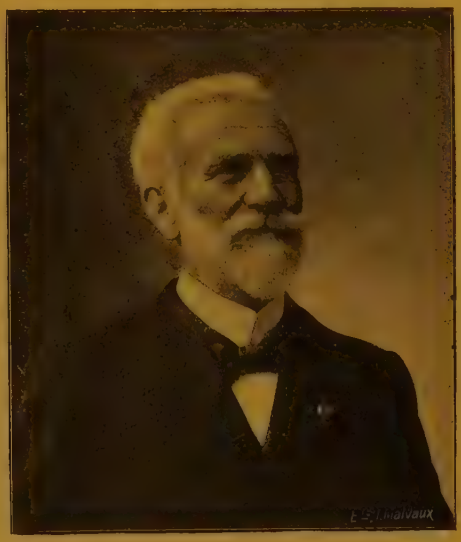
Principal dimensions and proportions of the Baldwin Diesel-electric locomotive.

Builder	Baldwin Locomotive Works.
Type	Diesel-electric.
Weights on drivers	180 000 lb.
Total weight	275 000 lb.
Wheel bases :	
Truck	12 ft. 8 in.
Total locomotive	30 ft. 4 in.
Diesel engine :	
Type	Knudsen, 12 cyl., 2 cycle.
Rated capacity	1 000 H. P.
Cylinders, diameter and stroke	9 3/4 inches by 13 1/2 inches.
Generator :	
Type	Westinghouse, 750 kw. d. c.
Voltage	750.
Motors :	
Number	4.
Type	Westinghouse. Type 853-D-3, 200 H. P.
Capacity of fuel tanks	750 gallons.
Length over couplers	52 ft. 1 3/4 in.
Diameter of wheels	40 inches.
Size of journals	7 1/2 inches by 14 inches.

OBITUARY

Edouard Joseph HOLEMANS,

Honorary « Inspecteur de direction » of the Belgian State Railways;
Secretary-Treasurer of the International Railway Congress Association;
Delegate to the ten sessions of the Congress (Brussels 1885 to London 1925).



The Permanent Commission of the International Railway Congress heard with the most profound regret of the death of their devoted Secretary-Treasurer, Mr. Edouard Holemans, who died at Malines on the 5 October 1925 at 82 years of age.

The news of his death affected us deeply and cannot but be felt by all those who at the London session in June last had the opportunity of noting the remarkable energy he displayed in spite of his great age. Lord Churchill, president of the session, at the opening meeting of the Congress, paid him a high compliment for the services he had rendered.

The loss of so devoted a colleague will cause universal regret throughout the International Railway Congress Association which he helped to found 40 years ago.

During this period, he was successively assistant-secretary and secretary-treasurer, and ever filled these offices in a most distinguished and tactful manner.

He took a prominent part in the organisation of the various Congresses which have been held since the inception of the Association, in America as well as in Europe.

He was entrusted by the Organising Commission with a confidential mission which he carried out with honour. His bearing towards all the members of the Congresses was always marked with the

greatest affability, which gave him in railway circles throughout the world solid and sincere friendships.

Mr. Holemans entered the service of the Belgian State Railways in 1861 at 18 years of age.

He mounted the various steps of the administration, and occupied successively various important positions.

He finished his administrative career as « Inspecteur de direction » in 1909 after 48 years service. In recognition of his great service, the Government awarded him the Cross of Commander of the Order of the Crown.

He was, in addition, an Officer of the Order of Leopold, holder of the Civic Cross of Belgium 1st Class, Chevalier of the Legion of Honour, Officer of Public Instruction of France, Officer of the Crown of Italy and Chevalier of the Order of St. Stanislas of Russia.

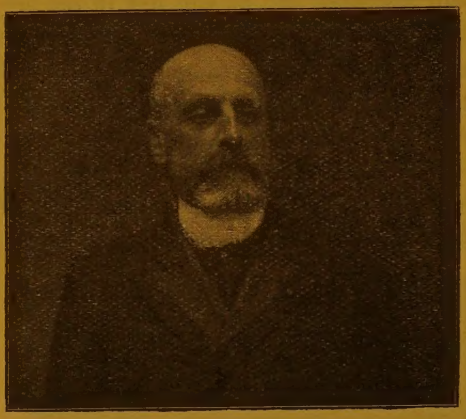
Mr. Holemans enjoyed the sympathy and esteem of all; he will live in the memory as an official of the highest type and a man of high mind, whose object through life was the conscientious fulfilment of his duty to the greatest degree.

We offer Madame Edouard Holemans and her children our deepest and sincere sympathy and our heart felt condolences.

The Executive Committee.

Constantin de BURLET,

Honorary Inspector General of Bridges and Roads;
Honorary General Manager of the Belgian National Light Railways;
Formerly a member of the Permanent Commission of the International Railway Congress Association;
Delegate to the sessions at Brussels (1885), Milan (1887), St. Petersburg (1892) and Rome (1922);
Reporter and Principal Secretary of the 5th section at Paris (1889);
Reporter at the sessions at London (1895), Paris (1900) and Washington (1905);
Reporter and Vice-President of the 5th section at the session at Berne (1910).



We have heard with very keen regret of the death of our esteemed and very distinguished old colleague, Mr. Constantin de Burlet, who died suddenly at Nivelles on the 11 November last.

Mr. de Burlet had taken part in our work as a delegate of the Belgian National Light Railways since the first session of the Congress held in Brussels in 1885. He had always taken the greatest interest in our Association and worked most devotedly at our meetings. He was elected a member of the Permanent Commission on the 25 May 1895.

The work he did as reporter on the following subjects at various Congresses was very much appreciated : « The working of secondary and light railways by leasing companies » (Paris 1889, and London 1895), « Influence of light railways on the national wealth » (Paris 1900), « Influence of light railways on the main lines » (Washington 1905), « Transhipment » (Berne 1910). He filled, with distinction, the offices of principal secretary of the 5th section (Light railways) at the sessions of Milan (1887) and Paris (1889) and of vice-president of the same section at the Berne Congress (1910).

When he retired from his position as General Manager of the Belgian National Light Railways, his colleagues on the Permanent Commission unanimously asked him to continue as a member of that Commission until the session held in Rome in 1922, and he agreed to serve.

Mr. Constantin de Burlet was born at Ixelles-lez-Bruxelles on the 14 May 1846.

He received his higher education at the School of Bridges and Roads at the University of Ghent and passed out in 1870.

Entering the Administration of Bridges and Roads in December 1870, he was raised to the rank of Inspector General on the 22 December 1908.

The manner in which he dealt with the laying out of new railway lines in the Provinces of Namur and Luxem-

burg brought him to the notice of the Government, who, when it was decided to form the Belgian National Light Railways in 1884, elected him as General Manager on the 5 August 1885.

Under his firm and clear direction, the National Railways reached a high degree of development and prosperity.

Mr. de Burlet was elected, in 1911, President of the International Union of Tramways, local railways and automobile transport, and was made Honorary President in 1924.

He was the author of a monograph on the « Light Railways of Belgium ». Full, clear and convincing, it has been of the greatest assistance to important undertakings established abroad.

He was Commander of the Order of Leopold, Grand Officer of the Order of the Crown of Belgium, Officer of the Legion of Honour, etc.

We offer to his family, in the name of the International Railway Congress Association, our sincere condolence.

The Executive Committee.

NEW BOOKS AND PUBLICATIONS

62 (02]

Molesworth's pocket book of engineering formulæ, 29th edition, revised and enlarged. — One volume of pocket book size (4 3/4 × 3 1/4 inches) of 938 pages with a number of tables and figures. — 1925, E. & F. N. Spon, Ltd., 57, Haymarket, London, S. W. 1, and Spon & Chamberlain, 120, Liberty Street, New York. — Price : 6 sh. net.

This pocket book, which is very well known to English engineers, answers its description perfectly. In spite of its very compact form (4 3/4 × 3 1/4 inches) it contains 872 pages which, in view of very careful arranging and printing, may be easily read.

The subjects dealt with are extremely numerous and diverse, and include nearly every branch of the engineers' art : public works, steel construction work, embankments, hydraulic engineering, steam engines, machines for pumping water and air, cranes and conveyors, machine parts, production of gas, marine engineering, aeronautics, metallurgy, etc.

A supplement consisting of about 110 pages is entirely devoted to the theory of applied electricity.

For almost any question which may arise, one will find in this book practical formulæ, methods of calculation, numerical coefficients dealing with the strength or properties of materials, methods of manufacture, rules adopted by competent bodies, rules laid down by the authorities, results of researches carried out by the best known scientists and experimenters.

In certain sections, the information given refers of course more especially to the country in which this work is published, but this does not affect its instructive nature. Moreover, those who use the metric system will find formulæ and numerical tables which they cannot directly use, but the conversion factors given in the first pages will allow them to make the necessary conversions.

Some very useful notes on mathematics and mechanics placed at the commencement of the book render it unnecessary to refer to special books. These are supplemented by mathematical and trigonometrical tables.

A general index placed at the end allows one to rapidly find the required information.

This short review does not permit one to give a complete idea of all the information put at the disposal of engineers in so complete a form. A brief glance will explain the success which has led to 29 editions being issued since its first appearance in 1862, and which have allowed it to be continually improved and kept in line with the unceasing progress of engineering science and its application.

E. M.